EARLY PROTEROZOIC MAGMATIC SUITES OF THE EASTERN CENTRAL MINERAL BELT (MAKKOVIK PROVINCE), LABRADOR: GEOLOGY, GEOCHEMISTRY AND MINERAL POTENTIAL

Andrew Kerr

Report 94-3

St. John's, Newfoundland

1994

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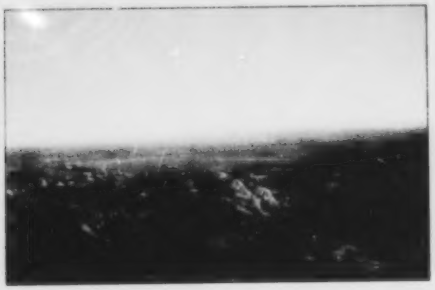

COVER

Panoramic view of the eastern part of the study area. White-weathering in foreground are recrystallized felsic volcanic rocks of the Upper Aillik Group. Low-lying islands in middle distance are composed of ca. 1800 Ma monzonites and syenites of the Numok Intrusive Suite and ca. 1720 Ma fluorite-bearing granites. Mountains in the distance are the Benedict Mountains, consisting mostly of ca. 1650 Ma, diorite, monzonite + syenite.

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ABSTRACT

The Early to Middle Proterozoic plutonic rocks of the eastern Central Mineral Belt (Makkovik Structural Province) are divided, on the basis of field relationships and geochronology, into Makkovikian and Labradorian plutonic assemblages, representing approximate time intervals of 1840 to 1720 Ma and 1670 to 1600 Ma, respectively. The Makkovikian assemblage includes both syn- and posttectonic associations, but precise U–Pb zircon ages mostly cluster around 1800 Ma, suggesting a single, main intrusive episode that transcended the deformation associated with the ca. 1800 Ma Makkovikian orogeny. The Labradorian assemblage is not associated with local deformation or metamorphism, but is probably a distal effect of the ca. 1650 Ma Labradorian orogeny, prevalent south of the study area. Both assemblages are broadly correlative with volcanic sequences of similar age and geochemical affinity; the Makkovikian assemblage is equivalent to parts of the Upper Aillik Group, whereas the Labradorian rocks are time-equivalents of the Bruce River Group.

The Makkovikian assemblage is dominated by siliceous, potassic, commonly porphyritic granites and alkali-feldspar granites, associated with subordinate monzonite to quartz syenite. High-silica-granite suites are commonly fluorite-bearing. In geochemical terms, most Makkovikian granitoids are metaluminous to slightly peralkaline, Fe-enriched, and enriched in Zr, Nb, Hf, REE, Zn and fluorine. A comparative analysis suggests that they are transitional in character between Phanerozoic post-orogenic (post-collisional) assemblages and 'A-type' or 'within-plate' granitoid assemblages. Similar enigmatic characteristics have been reported from Early Proterozoic granitoid batholiths elsewhere in the world.

The subordinate, bimodal, Labradorian plutonic assemblage comprises gabbro–diorite–monzonite–syenite suites, derived from mafic parental magmas, and an assortment of siliceous, generally leucocratic, granitoid rocks. Mafic rocks resemble high-K calc-alkaline or shoshonitic basalts, and their associated felsic differentiates are enriched in Rb, Cs, Th, and U, as a consequence of prolonged fractionation. Other Labradorian granites (ss) are metaluminous to peraluminous in composition, and depleted in Zr, Nb, Hf, REE, Zn and fluorine, indicating that they had quite different sources from their Makkovikian counterparts.

The area is characterized by numerous small mineral occurrences, and larger, subeconomic U and Mo deposits. The most abundant commodities are U, F, Mo, Cu, Pb and Zn, although there are minor occurrences of Au and Ag. Research undertaken in association with this study suggests that many of these are epigenetic–hydrothermal features that are genetically linked to evolved posttectonic granitoid rocks of both Makkovikian and Labradorian age. Other mineral occurrences, notably U in the Upper Aillik Group, also bear a general relationship to earlier felsic plutonism and volcanism. The presence of multiple cycles of felsic magmatism, each associated with concentration of ore elements, is a feature of some 'granophile' mineral provinces, and the area may have potential for these targets. An analysis of geochemical patterns amongst the granitoid suites indicates that several units have compositions that resemble those of known specialized granites.

INTRODUCTION

PROJECT OVERVIEW

This project was initiated in 1985, to evaluate the mineral potential of abundant plutonic rocks in the eastern Central Mineral Belt of Labrador (Figure 1). It also investigated the geochronological and petrological relationships amongst plutonic suites and possible equivalent supracrustal sequences. This was not a mapping project (*ss*), as the project area had already been covered by a regional 1:100 000-scale geological survey. However, because mapping in the Central Mineral Belt (CMB) has traditionally been biased toward supracrustal sequences, field work under this project has led to some revision of plutonic units, particularly in inland areas. The most extensive changes are in the northwestern part of NTS 13J (1:250 000 scale). In other parts, unit boundaries and distributions remain essentially unchanged from previous work, although the grouping and subdivision of plutonic units may differ from earlier interpretation.

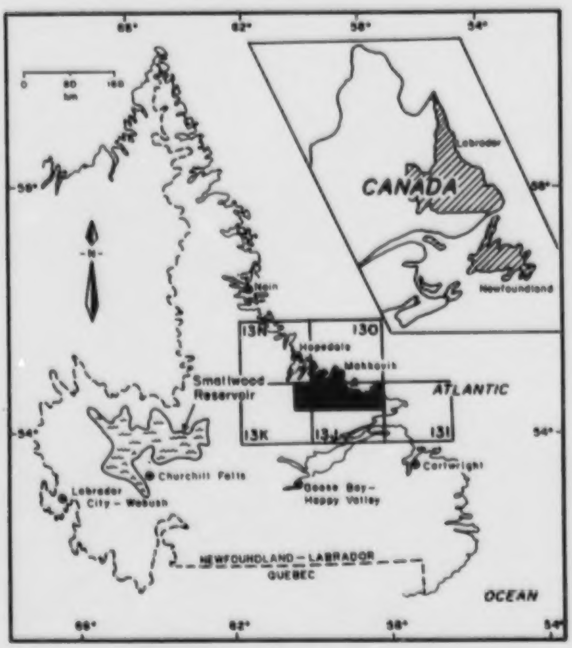


Figure 1. *Location of the study area.*

This project was coordinated with detailed metallogenic studies conducted by Dr. Derek Wilton and his research students Craig MacDougall and Leonard MacKenzie at the Department of Earth Sciences/Centre for Earth Resources Research of Memorial University. This project also provided a framework for a Ph.D. thesis conducted by the author at Memorial University of Newfoundland. The study addressed a number of petrogenetic and regional geological topics, including isotopic studies that are not covered by this report.

LOCATION, TOPOGRAPHY AND ACCESS

The study area is located approximately 150 km northeast of Goose Bay (Figure 1), and includes the northern half of NTS map sheet 13J, the eastern edge of NTS map sheet 13K, and the southern edge of NTS map sheet 13O. A rugged, well-exposed, mountainous terrain, with a maximum elevation of 875 m, dominates eastern and northern portions of the area. The coastline is incised by several deep fiords (e.g., Makkovik Bay) and is protected from the rough waters of the Labrador Sea by numerous offshore islands. The southern and western parts of the study area consist of a variably wooded, boulder-strewn plateau that is largely obscured by glacial drift, with the exception of hilltops and watercourses. Summer conditions prevail from late June to late August, and are an extreme mixture of cold, damp weather and hot, humid, fly-infested periods.

The community of Makkovik (Figure 1) is served by Marine Atlantic coastal boat service from June to November, and by year-round scheduled flights. This project was operated from Makkovik, from a dormant mineral exploration camp at Melody Lake, near Postville, and from temporary camps at Adlavik Bay and Tukialik Bay.

The coastline provides access to some of the northern and eastern parts of the area, but easy access to the hinterland is possible only by air. Numerous lakes provide good access for float-equipped aircraft, and gravel runways are present at Makkovik and Postville. Helicopter support is essential for regional studies of this type, but localized exploration work in inland areas can be carried out effectively on foot, or with boat or all-terrain vehicle support.

PREVIOUS WORK, 1814 TO 1985

Geological research on the coast of Labrador commenced with the work of Steinhauer (1814). This, and subsequent studies (e.g., Lieber, 1860; Packard, 1891; Daly, 1902), consisted mostly of descriptions of coastal outcrops. The first mapping in coastal areas was conducted by the Newfoundland Geological Survey and Geological Survey of Canada (Kranck, 1939, 1953; Christie *et al.*, 1953; Douglas, 1953). Geological mapping (at a 1:250 000 scale), including coverage of inland areas, was completed by the Geological Survey of Canada in the 1970s (Stevenson, 1970; Taylor, 1975).

In 1954, Murray Piloski of British Newfoundland Exploration Company Ltd. (BRINCO) discovered pitchblende near Makkovik. This led to a 25-year period of uranium, molybdenum and base-metal exploration by BRINCO and several joint venture partners (see Gower *et al.*, 1982 and Ryan, 1984, for details). Most of the exploration and research work from 1955 to 1978 was related to the search for economic mineralization in uranium-bearing supracrustal sequences.

Many of these studies remain confidential, but some general results were published by BRINCO geologists (e.g., Beavan, 1958; Gandhi *et al.*, 1969; Gandhi, 1978). Uranium deposits at Kitts and Michelin were evaluated for commercial development in the late 1970s. Several more general studies with economic implications were carried out via university theses supported partly by BRINCO. These included documentation of mineralization (e.g., Gill, 1966; Barua, 1969), and also regional geological and structural syntheses (Clark, 1973, 1979; Marten, 1977) in the Makkovik and Kaipokok Bay areas. The study of Marten (1977) was particularly influential in unravelling the structural evolution of the area. A third group of studies emphasized petrological and geochemical studies of uranium-bearing volcanic rocks (White, 1976; Evans, 1980).

The Newfoundland Department of Natural Resources (NDNR) started work in the area in 1976 and completed regional 1:100 000 scale mapping by 1980 (Bailey, 1979; Bailey *et al.*, 1979; Ryan and Harris, 1978; Doherty, 1980; Gower, 1981). Compilation and synthesis of this information was presented by Gower (1981) and Gower *et al.* (1982) for the eastern part (NTS 13J and 13O) and by Bailey (1979) and Ryan (1984) for the western part (NTS 13K). These programs focussed mostly on supracrustal sequences, but the areal importance of plutonic rocks was recognized, as was their polyphase and compositionally variable nature.

PROJECT ACTIVITY, 1985 TO 1990

Re-examination and sampling of a number of mineral occurrences in the study area during 1984 (Wardle, 1984; Wardle and Wilton, 1985) awakened interest in both the gold potential and the possible importance of granitoid rocks as hosts or as progenitors for other types of mineralization. This project commenced with geochemical sampling and mapping in 1985, leading to revision of existing unit designations and definition of new regional granitoid units (summarized by Kerr, 1986). Analysis of geochemical data from 1985 led to the identification and delineation of several granitoid associations considered to have some of the characteristics of specialized granites (summarized by Kerr, 1987). The 1986 field season included follow-up mapping and sampling in these areas, and extension of regional coverage eastward into the Benedict Mountains. The 1987 field season included limited follow-up work in the Benedict Mountains area, and also an assessment of the Platinum-Group-Element (PGE) potential of mafic intrusive rocks (Kerr, 1988a). The petrology and geochemistry of possible specialized granitoid rocks in the area was summarized by Kerr (1988b). A preliminary open-file report containing raw geochemical data and element-distribution maps was also released at this time (Kerr, 1988c), but is superseded by this final report. Kerr and Krogh (1990) and later Kerr *et al.* (1992) summarized the results of U–Pb geochronological studies, and also some aspects of Ph.D. thesis work conducted by Kerr (1989a). Kerr (1989b) and Kerr and Fryer (1990) presented some preliminary geochemical and isotopic data in external publications. More recently, Kerr and Fryer (1993, 1994) have presented further discussions of isotopic data in relation to the origin of A-type granites and crustal growth issues.

METHODS

Much of the work discussed herein is derived from large-scale, structured, lithogeochemical sampling programs inspired by methodology commonly employed in exploration geochemistry (e.g., Garrett, 1983). The system used resembles that employed by Dickson (1983) in the Ackley Granite project. In addition to defining element-enrichment patterns that may indicate metallogenic specialization, lithogeochemistry is a valuable adjunct to mapping in granitoid rocks, as it helps to group intrusive rocks of similar affinity and petrogenesis.

The first stage was the completion of a helicopter-assisted regional survey based on a series of 2 by 2 km grid cells defined by the UTM coordinate grid lines superimposed on 1:50 000-scale topographic maps. Within each grid cell, a sample site was selected on a random basis, with selection of additional sites where grid cells straddled previously defined unit boundaries. In the field, samples were collected as close to their preselected locations as feasible. Geochemical samples were collected at all sites, and details of geological relationships were noted. Follow-up surveys in areas of interest, defined by the regional program, were conducted in an analogous manner, but employed a high-density grid system based on 1 by 1 km cells. Some follow-up surveys were also conducted as part of ground traverses, which allowed a more detailed examination of geological relationships in key areas. The above lithogeochemical surveys were augmented by ground traverses in areas of particular interest or key field relationships, and by boat-assisted mapping of coastal areas and their immediate hinterland.

These methods facilitate coverage of large areas, but also preclude detailed work to define and examine contacts, especially in inland areas. The locations of contacts between plutonic rocks in such areas are generally positioned only approximately, and relationships between some units must be inferred from other types of data, notably geochronology. These limitations are inherent in a large-scale project of this type.

REPORT ORGANIZATION AND FORMAT

This report is presented in seven sections. Section 1 is the Introduction. Section 2 (Geological Framework) provides an overview of the geology of the project area and introduces subdivisions of plutonic rocks that are used as a framework for subsequent discussion. Section 3 (Geology and Petrology) contains descriptions of principal rock types and their field relationships. Section 4 (Granite-Related Mineralization) reviews the characteristics of known mineral occurrences in

the study area that probably bear a genetic relationship to granitoid plutonic rocks, and is largely summarized from a forthcoming memoir on the metallogenesis of the Central Mineral Belt (Wilton, *in press*). Section 5 (Descriptive Geochemistry) is devoted to descriptive geochemical information, using tables of average compositions and selected variation diagrams to characterize units and suites. Section 6 (Comparative Geochemistry) is a comparative geochemical analysis, assessing the differences between granitoid associations and their probable affinities and tectonic setting(s). This section also evaluates various plutonic suites in terms of 'geochemical specialization' and compares them to specialized granites known from other areas. A detailed assessment of the geochemical and isotopic data collected during this project, particularly as applied to petrogenetic problems, is given in Kerr (1989a). Section 7 (Discussion and Conclusions) summarizes and discusses the principal results of this work, and makes recommendations for future work.

Appendices to this report include a microfiche listing of geochemical data, complete with sample coordinates (Appendix 1). Individual sample location maps are not included in this report due to the large number that would be required. A series of 1:250 000-scale geochemical variation maps, which illustrate regional variation patterns amongst the intrusive rocks using a proportional-symbol method, are also included in microfiche format (Appendix 2). For a discussion of spatial variation patterns by element, see Kerr (1988c).

The geology of intrusive rocks and distribution and extent of newly defined plutonic units are illustrated with a summary 1:250 000-scale geological map of the entire project area (Map 94-216). This replaces the preliminary 1:250 000-scale geological map presented by Kerr (1988c).

GEOLOGICAL FRAMEWORK

REGIONAL GEOLOGY

The geology of Labrador is illustrated and discussed by Greene (1974) and R. Wardle (unpublished data). Labrador is divided into five Precambrian structural provinces (Figure 2), based on trends and 'stabilization events' defined by Rb–Sr and K–Ar age data (after Stockwell, 1972). The Nain and Superior provinces are of Archean age (stabilized between 2800 and 2500 Ma), and are separated by the Proterozoic Churchill Province (stabilized ca. 1800 Ma). The Nain Province is part of the North Atlantic Archean Craton (Bridgwater *et al.*, 1973), and was originally continuous with west Greenland (Figure 2). The Nain Province is bounded to the southeast by the Proterozoic Makkovik Province (Gower and Ryan, 1986; Makkovik Subprovince of Taylor, 1971), which was mostly stabilized by ca. 1800 Ma, but includes some ca. 1650 Ma old intrusive rocks. The eastern part of the Central Mineral Belt is almost entirely located within the Makkovik Province.

The southern part of Labrador forms part of the Grenville Province, which was stabilized by ca. 1100 Ma. Geochronological studies completed since 1980 (e.g., Wardle *et al.*, 1986; Thomas *et al.*, 1986) have demonstrated that gneisses in the Labrador portion of the Grenville Province were formed and/or metamorphosed by ca. 1650 Ma. Mapping has shown that it is composed of a number of thrust-bounded terranes that were assembled into their current positions during or prior to the Grenvillian Orogeny. These terranes represent a structurally reworked belt of ca. 1650-Ma old crust named the Labrador Orogen (Thomas *et al.*, 1986), and are termed the Labradorian high-grade terranes. The interface between the high-grade terranes and older structural provinces to the north is marked by the Trans-Labrador batholith or Trans-Labrador granitoid belt (TLGB), discussed in more detail below.

In addition to the major structural provinces discussed above, the Nain and Churchill provinces are intruded by anorogenic gabbro–anorthosite–granite plutons of ca. 1500 to 1300 Ma age (e.g., Emslie, 1978).

Trans-Labrador Granitoid Belt

The TLGB corresponds generally to the Trans-Labrador batholith, as defined initially by Wardle *et al.* (1982). This feature (Figure 2) was generally considered to be of ca. 1650 Ma age and to be part of the Labrador Orogen (Wardle *et al.*, 1986). Undeformed plutonic rocks in the eastern Central Mineral Belt have previously been grouped with this 'Trans-Labrador batholith' (e.g., Gower and Ryan, 1986; Kerr, 1986, 1987). Rb–Sr and U–Pb geochronology conducted as part of this project demonstrate, however, that undeformed plutonic rocks in the study area include suites of ca. 1650 Ma, ca. 1720 Ma and ca. 1800 Ma age (Kerr *et al.*, 1992). The oldest of these are similar in age to foliated granitoid rocks that had previously been recognized as a distinct, older, assemblage associated with the ca. 1800 Ma Makkovikian Orogeny (Gower and Owen, 1984; Gower and Ryan, 1986).

The TLGB, as defined here, includes both foliated and undeformed Early Proterozoic plutonic rocks. The older and younger components of the belt are termed Makkovikian and Labradorian assemblages respectively, with reference to the crust-formation events with which they appear to be broadly associated (see below). The ca. 1720 Ma plutonic rocks are grouped with the older (Makkovikian) assemblage on compositional grounds. The term 'granitoid belt' is preferred over 'batholith', as it more clearly indicates the probable composite nature of the belt.

Makkovikian plutonic rocks are further subdivided into syntectonic and posttectonic associations. These are compositionally similar and are regarded as closely related.

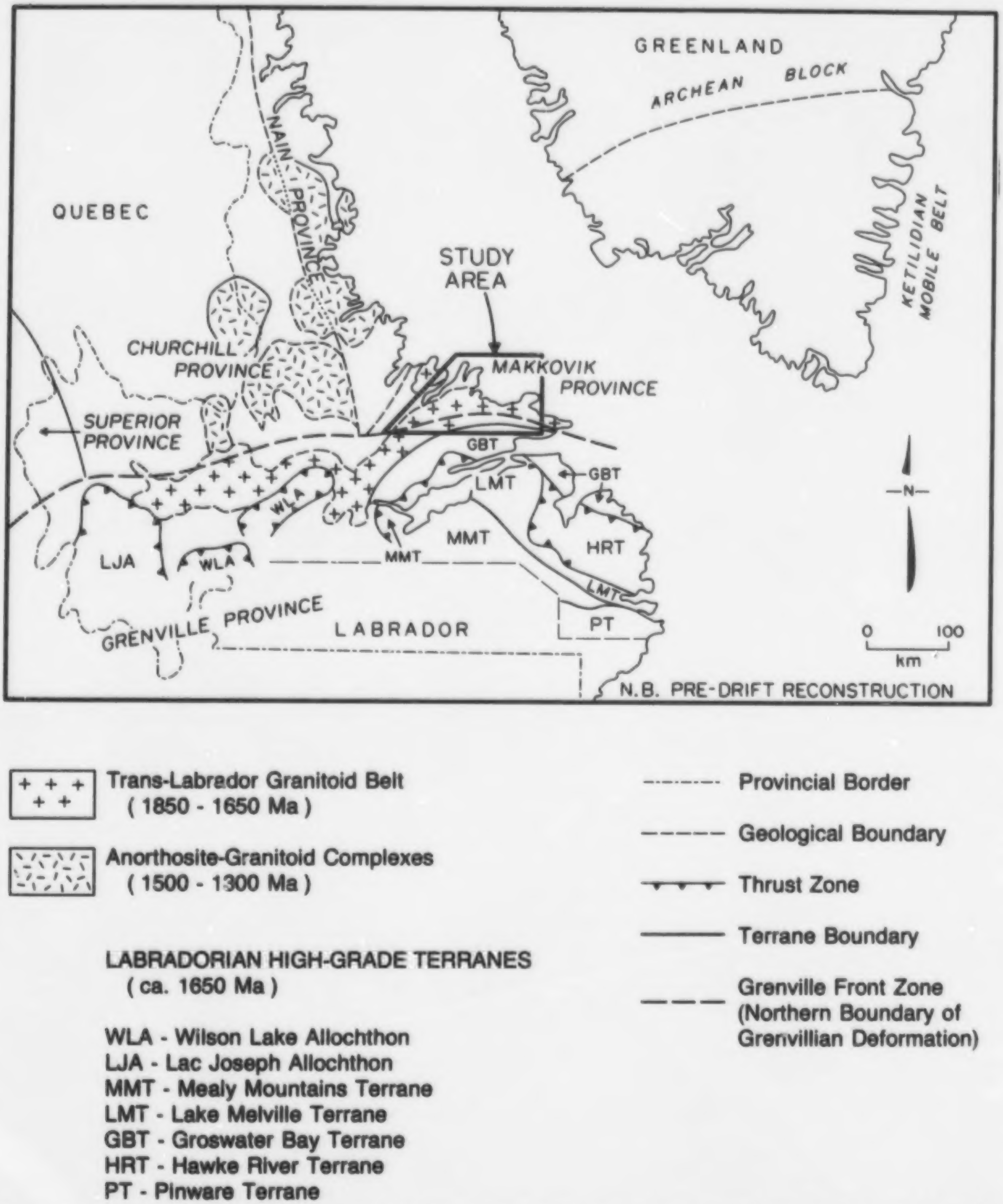


Figure 2. *Structural provinces and geotectonic elements in central and eastern Labrador, and formerly adjacent Greenland (after Gower and Ryan, 1986, with the addition of more recent work in the Grenville Province).*

Rb–Sr and U–Pb geochronological data indicate that they are also, partly, of similar age. The distinction is convenient for descriptive purposes, although their syn- and posttectonic characteristics may simply reflect heterogeneous late Makkovikian deformation, rather than significant differences in their times of emplacement.

Table 1. Summary of the geological history and lithological units of the Makkovik Province and adjacent parts of Labrador.
1a. Summary of the geological evolution of the study area

TIME Ma	DESCRIPTION OF EVENTS
< 1000	Emplacement of mafic dykes of several ages, deposition of Late Proterozoic Double Mer Formation in rift or graben basins of the Lake Melville area.
1200–1000	Grenvillian Orogeny. Thrusting and metamorphism south of Grenville Front Zone, minor effects in Makkovik Province.
1450–1300	Emplacement of Michael Gabbro (ca. 1430 Ma). Minor gabbro to syenite intrusions in adjacent Labradorian high-grade terranes. Emplacement of anorthosite–granite intrusions in Nain and Churchill provinces.
1670–1600	Emplacement of Labradorian plutonic rocks (gabbro, diorite and granitoids). Extrusion of Bruce River Group volcanic rocks and possibly some volcanic rocks in Makkovik Province. Emplacement of ca. 1.65 Ga plutonic rocks following deformation/metamorphism in adjacent high-grade terranes.
1800–1720	Emplacement of posttectonic Makkovikian intrusive rocks (quartz monzonite to granite), possibly coeval with localized late deformation (see below).
ca. 1800	Makkovikian Orogeny: last major deformation of Upper Aillik Group and early granitoid rocks.
1850–1800	Emplacement of syntectonic and late-tectonic Makkovikian plutonic rocks (quartz monzonite to granite). Some are similar in age to undeformed Makkovikian granites suggesting that deformation may have been heterogeneous. Extrusion of parts of the Upper Aillik Group sequence.
ca. 1860	Extrusion of earliest known volcanic rocks in the Upper Aillik Group.
?	Early deformation and metamorphism of Lower Aillik Group. This may postdate deposition/extrusion of earliest Aillik Group.
1910–1890	Emplacement of oldest known granitoid rocks. May predate deposition of Lower Aillik Group.
pre-1890	Earliest deformation in Moran Lake Group and refoliation of Archean gneiss complex.
2000–1860	Deposition of sedimentary and volcanic rocks of the Moran Lake Group and Lower Aillik Group.
2230–1900	Deformation and migmatization of Archean basement (Iggiuk Event of Ryan *et al.*, 1983).
2500–2000	Emplacement of mafic dyke swarms into Archean gneiss complex. Probably more than one generation of dyke. Recent dating of dykes (Cadman *et al.*, 1993) suggests an age of 2230 Ma.
2800–2500	Stabilization of Archean gneiss complex.

With regard to terminology, it should be noted that the terms syn- and posttectonic are used with reference to late deformational events associated with the Makkovikian Orogeny of Gower and Ryan (1986), which produced the dominant northeast–southwest structural trends of the eastern Makkovik Province. Because the southern part of the area has been variably affected by Grenvillian deformation, rocks described as 'posttectonic Makkovikian' and 'Labradorian' are in places deformed, and show east–west trending Grenvillian fabrics. At first sight, this appears slightly contradictory, but most alternative terminological frameworks encounter similar problems; for example, if 'synorogenic' is chosen, then there are problems of defining the period of orogeny. For this reason, the original terminology used by Kerr (1989a) and Kerr *et al.* (1992) has been retained in this report. Wherever possible, the qualifier 'Makkovikian' has been used in conjunction with the time terms.

GEOLOGY OF THE STUDY AREA AND ADJACENT REGIONS

The geological evolution of the Makkovik Province is depicted in simplified form in Table 1. It is subdivided into several lithological packages, which are indicated in Figure 3.

Archean Metamorphic Rocks

Archean gneisses are exposed in the northwest Makkovik Province, and in the adjacent Nain Province (Ryan *et al.*, 1983; Korstgård and Ermanovics, 1985). They represent probable basement material for the western portion of the study area. They comprise banded quartzofeldspathic orthogneiss (possibly as old as 3100 Ma; Loveridge *et al.*, 1987), containing lenses of even older amphibolite and

Table 1. *(Continued).* Summary of the geological history and lithological units of the Makkovik Province and adjacent parts of Labrador. **1b.** Units and intrusive suites used and/or defined in this report. (WR = whole rock)

	Intrusive Suite	Unit(s)	Probable Age	Comments
LABRADORIAN PLUTONIC ROCKS	not named	Otter Lake–Walker Lake granite (name after Ryan, 1984)	1647 ± 2 Ma (U–Pb, zircon) (Kerr *et al.*, 1992) 1550 ± 55 Ma (Rb–Sr, WR) (Kontak, in Ryan, 1984)	Regionally extensive unit ranging in composition from quartz monzonite to granite.
	Monkey Hill Intrusive Suite	Monkey Hill granite Little Monkey Hill granite Duck Island granite Bent's Cove granite Round Pond granite Kidlaluit Granite	Monkey Hill granite : ca. 1640–1650 Ma (U–Pb, zircon) (Kerr *et al.*, 1992) Round Pond Granite : 1620 ± 60 Ma (K–Ar, biotite) (Wanless *et al.*, 1970)	Consists of a number of small, epizonal plutons comprising fine-grained leucogranite. Little Monkey Hill granite cuts gabbro and diorite of Adlavik Intrusive Suite.
	not named	Burnt Lake granite Witchdoctor granite	1548 ± 90 Ma (Rb–Sr, WR) (MacKenzie and Wilton, 1988) 1632 ± 9 Ma (U–Pb, zircon) (Brooks, 1982)	Leucocratic granite units, probably two phases of the same body. Locally similar to Monkey Hill Intrusive Suite granites.
	Mount Benedict Intrusive Suite	(units not named) Gabbro to diorite unit Monzonite to syenite unit Syenite to granite unit	1649 ± 3 Ma (U–Pb, zircon) (Kerr *et al.*, 1992) 1625 ± 50 Ma (Rb–Sr, WR) (Brooks, 1982)	Layered assemblage, diorite and gabbro at base, evolved syenite at the top. Gabbro and diorite are very similar to Adlavik Intrusive Suite.
	Adlavik Intrusive Suite	(units not named) Diorite to monzonite unit Gabbro and leucogabbro unit	1649 ± 1 Ma (U–Pb, zircon) (Kerr *et al.*, 1992)	Polyphase layered mafic intrusion, evolving to diorite and monzonite. Parts of suite resemble Mount Benedict Intrusive Suite.
POST-TECTONIC MAKKOVIKIAN PLUTONIC ROCKS	not named	Stag Bay granodiorite	1714 ± 44 Ma (Rb–Sr, WR) (Kerr, 1989a) ca. 1800 Ma (U–Pb, zircon) (Kerr *et al.*, 1992)	Affinity uncertain.
	not named	Freshsteak granitoid Noarse Lake granitoid	Freshsteak granitoid : 1798 ± 48 Ma (Rb–Sr, WR) (Kerr, 1989a)	Closely similar melanocratic quartz monzonite to monzogranite. probably Makkovikian age.
	not named	Big River Granite	1798 ± 28 Ma (Rb–Sr, WR) (Kerr, 1989) 1802 ± 2 Ma (U–Pb, zircon) (Kerr *et al.*, 1992)	Regionally extensive granite unit with mantled-feldspar texture.
	Strawberry Intrusive Suite	Bayhead granite Cape Strawberry granite October Harbour granite Dog Islands granite Tukialik granite	1719 ± 3 Ma (Kerrr *et al.*, 1992) 1694 ± 56 Ma (Rb–Sr, WR) (Kerr, 1989a)	Array of epizonal plutons of closely similar, coarse-grained biotite granite, commonly K-feldspar porphyritic, and fluorite-bearing.
	Lanceground Intrusive Suite	Lanceground Hills granite Pistol Lake granite Tarun granite	Lanceground Hills granite : 1692 ± 32 Ma (Rb–Sr, WR) (Kerr, 1989a) [Age is considered disturbed]	Coarse grained, locally hypersolvus, quartz syenite to granite plutons, with abundant zircon, allanite, fluorite.
	Numok Intrusive Suite	(units not named) Monzonite to quartz monzonite Syenite to quartz syenite	1801 ± 2 Ma (U–Pb, zircon) (Kerr *et al.*, 1992)	Coarse-grained monzonite to quartz syenite. Some syenitic rocks resemble Lanceground Intrusive Suite.

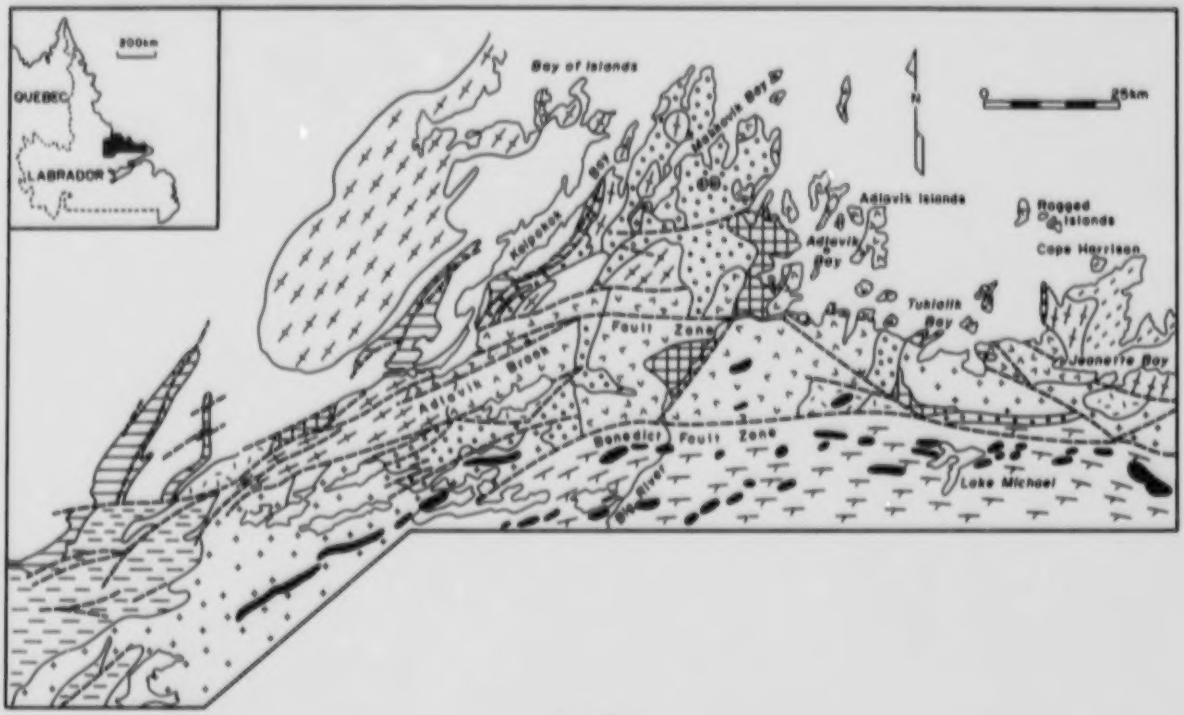
Table 1. *(Continued).* Summary of the geological history and lithological units of the Makkovik Province and adjacent parts of Labrador. **1b.** Units and intrusive suites used and/or defined in this report

	Intrusive Suite	Unit(s)	Probable Age	Comments
SYNTECTONIC MAKKOVIKIAN PLUTONIC ROCKS	not named	Long Island Quartz Monzonite (after Gower *et al.*, 1982)	1802^{+13}_{-9} Ma (U–Pb, zircon) (Gandhi *et al.*, 1988; Kerr *et al.*, 1992)	Foliated, melanocratic quartz monzonite
	not named	Melody Granite	age unknown	Strongly foliated granite
	not named	Brumwater granite Pitre Lake granite Manak Island granodiorite	ages unknown, but foliation suggests ≥ 1800 Ma for all.	Small, leucocratic granitoid units.
	not named	Deus Cape granodiorite	1837^{+6}_{-4} Ma (U–Pb, zircon) (Kerr *et al.*, 1992)	Part of a regionally extensive unit exposed east of study area.
	Kennedy Mountain Intrusive Suite	Kennedy Mountain granite Narrows granite Cross Lake granite Other (not named)		Coarse grained, foliated, K-feldspar porphyritic granite, commonly fluorite-bearing.
	Island Harbour Bay Intrusive suite (after Ryan *et al.*, 1983)	(units not named)	1805 ± 5 Ma (U–Pb, zircon) (Loveridge *et al.*, 1987) (coarse-grained granite only)	Complex, polyphase tonalite to granite intrusion emplaced into Archean gneiss complex.
UNCLASSIFIED PLUTONIC ROCKS	not named	Thunder Mountain syenite Jeanette Bay quartz syenite	undated	Small, massive syenitic bodies of uncertain affinity.
	not named	Granitoid gneisses South of Benedict fault zone	undated	Probably represents deformed equivalents of both Makkovikian and Labradorian assemblages.

paragneiss. These orthogneisses are intruded by sodic granitoid rocks dated at ca. 2800 Ma (Loveridge *et al.*, 1987), and by several generations of mafic dykes. In the Makkovik Province, all of these rocks have been affected by Early Proterozoic orogenic events termed the Makkovikian Orogeny (Gower and Ryan, 1986), and also possibly by earlier events. The degree of metamorphic and structural reworking of the Archean increases from northwest to southeast toward Kaipokok Bay (Ryan and Kay, 1982). Small areas of similar gneisses occur southeast of Kaipokok Bay, interspersed with the Aillik Group and as enclaves between plutonic units. These are undated, but are generally presumed also to be of Archean age (Gower *et al.*, 1982).

Cape Harrison Metamorphic Suite

The Cape Harrison Metamorphic Suite (Gower, 1981) is the oldest recognized component of the eastern study area (Figure 3). It consists of massive to banded orthogneiss, ranging in composition from diorite to granodiorite, with lesser amounts of foliated granodiorite and granite. In terms of field appearance, the gneisses resemble Archean gneisses. Brooks (1983) obtained a Rb–Sr errorchron age of 1740 ± 85 Ma, with a low initial ratio of 0.7034 that apparently precludes extensive crustal prehistory. Nd isotopic compositions (Kerr, 1989b; Kerr and Fryer, 1993) also indicate that the suite is unlikely to be older than 2100 Ma, and must, therefore, represent Proterozoic material, which



LEGEND

SUPRACRUSTAL SEQUENCES

Bruce River Group:
sandstone, conglomerate, arkose, mafic to felsic volcanic rocks

Upper Aillik Group:
predominantly felsic volcanic rocks and minor metasedimentary rocks

Moran Lake Group and Lower Aillik Group:
metasedimentary rocks and mafic metavolcanic rocks

ARCHEAN BASEMENT ROCKS

Quartzofeldspathic banded orthogneiss, amphibolite, foliated granitoid rocks

KEY

----- Major Fault (approximate)

—— Geologic Contact (approximate)

PLUTONIC IGNEOUS ROCKS

Michael Gabbro Suite

Plutonic rocks of uncertain age

LABRADORIAN PLUTONIC ROCKS

Granitoid rocks (mostly quartz monzonite to granite

Gabbro and diorite (includes Adlavik Intrusive Suite)

MAKKOVIKIAN PLUTONIC ROCKS

Massive, posttectonic quartz monzonite to granite

Foliated, possibly syntectonic quartz monzonite to granite. May include some pre-Makkovikian material

METAMORPHIC ROCKS

Granitoid gneisses of the Grenville Province:
foliated granites and gneisses, probably deformed and reworked equivalents of Makkovikian and Labradorian plutonic rocks

Cape Harrison Metamorphic Suite:
tonalitic gneisses and foliated granitoid rocks of Makkovikian or pre-Makkovikian age

Figure 3. *Simplified geological map of the study area.*

has undergone a period of high-grade metamorphism apparently not recorded by adjacent Makkovikian plutonic rocks. Thus, it is the only regionally extensive candidate for 'basement' in the eastern part of the study area.

Moran Lake and Lower Aillik Groups

The Moran Lake and Lower Aillik groups are Early Proterozoic supracrustal rocks of uncertain (but certainly ≥ 1800 Ma) age that are dominated by metasedimentary and mafic volcanic rocks. The Moran Lake Group (Ryan, 1984) rests unconformably upon Archean gneisses in the west of the Makkovik Province. It consists of a lower sedimentary sequence including quartzite, shale, dolostone and iron formation, overlain by mafic volcanic rocks. These rocks have been metamorphosed to greenschist facies, and are moderately deformed (Ryan, 1984).

The Lower Aillik Group (described by Gandhi, 1978; Gower *et al.*, 1982) is exposed in a zone of intense folding and thrusting along Kaipokok Bay and consists of arenaceous to pelitic metasedimentary rocks overlain by mafic metavolcanic rocks. It is at least 1860 Ma old, based on U−Pb ages from the overlying Upper Aillik Group, and granitoid plutons that intrude it. The contact between the Lower Aillik Group and the Archean basement southeast of Kaipokok Bay is a mylonite zone (Marten, 1977), and a number of similar structures (interpreted as slides or thrusts) occur in higher parts of the sequence. It may have been deposited as a cover sequence upon the Archean, but no unconformity is preserved. The Lower Aillik Group was metamorphosed to amphibolite facies, and underwent several phases of folding (Marten, 1977; Gower *et al.*, 1982).

The similarity between the stratigraphy and setting of these Moran Lake and Lower Aillik groups suggests that they are probably stratigraphic equivalents (Wardle and Bailey, 1981; Gower and Ryan, 1986).

Upper Aillik Group

The Upper Aillik Group (described by Gandhi, 1978 and Gower *et al.*, 1982) consists of felsic volcanic and volcaniclastic rocks, related volcanogenic sedimentary rocks and subvolcanic intrusions. The volcanic rocks yield U−Pb zircon ages of ca. 1860 and 1807 Ma (Schärer *et al.*, 1988), suggesting at least two episodes of volcanism. The relationship between Lower and Upper Aillik groups is unclear; their mutual contact is a mylonite zone that may represent a modified unconformity (Marten, 1977), but it remains possible that the 'Upper' Aillik Group is of similar age to, or possibly older, than the 'Lower' Aillik Group.

The stratigraphy of the Upper Aillik Group is poorly known; in general, it consists of a lower sequence of sandstone, arkose, conglomerate and tuff overlain by a massive accumulation of dacitic to rhyolitic flows and pyroclastic rocks (Gower and Ryan, 1987). The sequence is variably metamorphosed, but is generally at or below greenschist facies; some parts of the sequence show little or no evidence of deformation. Volcanic sequences in the eastern study area are included with the Upper Aillik Group in Figure 3 (after Gower, 1981), but are undated; some undeformed examples may be younger.

Syntectonic Makkovikian Plutonic Rocks

These granitoid plutons have northeast or north-northeast-trending foliations. In the Kaipokok Bay area, they intrude the Archean gneisses, Lower Aillik Group and parts of the Upper Aillik Group, and cut early structures, but share the general northeast structural trends of these units. Therefore, they are viewed as syntectonic with respect to overall multiphase deformation during the Makkovikian orogeny, and were affected by at least the latest Makkovikian deformational events (Marten, 1977). In an alternative explanation (Gower, 1993), they could be viewed as intratectonic, but the terminology of Kerr *et al.* (1992) is retained here. Published U−Pb zircon, Rb−Sr and K−Ar ages from these rocks are mostly between 1840 and 1800 Ma (Loveridge *et al.*, 1987; Gandhi *et al.*, 1988; Kerr *et al.*, 1992). They include quartz monzonite, granodiorite and fluorite-bearing granite around Makkovik Bay, and a large, complex, polyphase tonalite-granite body that intrudes the reworked Archean gneisses north of Kaipokok Bay. Granitoid rocks in the east of the study area, near Cape Harrison, also have northeast-trending foliations (Gower, 1981), and have been dated at ca. 1837 Ma (U−Pb; Kerr *et al.*, 1992). Brooks (1983), Gandhi *et al.* (1988) and Kerr *et al.* (1992) report ages greater than 1890 Ma from poorly-known foliated granites to the west. The extent and significance of this earlier (pre-Makkovikian or early Makkovikian ?) magmatism is presently unclear.

Posttectonic Makkovikian Plutonic Rocks

These are massive, unfoliated plutonic rocks that intrude the Upper Aillik Group. They comprise monzonite−quartz and monzonite−syenite intrusions, as well as granite to alkali-feldspar granite plutons that are commonly fluorite-bearing. U−Pb and Rb−Sr ages of ca. 1800 Ma from some units are similar to those from syntectonic Makkovikian plutonic rocks, and it is likely that both groups represent a single pulse of magmatism that transcended late Makkovikian deformation (Kerr *et al.*, 1992). This is supported by the geochemical similarities between them, discussed in detail in the Comparative Geochemistry section. Some posttectonic Makkovikian plutonic rocks are now known to be of ca. 1720 Ma age (Kerr *et al.*, 1992), but share the geochemical characteristics of units known to be of ca. 1800 Ma age.

In the south, these rocks locally have east−west trending foliations that probably result from Grenvillian deformation. These are most evident adjacent to major east-trending structures such as the Adlavik Brook and Benedict fault zones.

Labradorian Plutonic Rocks

The TLGB Labradorian assemblage consists mainly of undeformed plutonic rocks that intrude the Upper Aillik Group and Makkovikian plutonic rocks. They include layered

gabbro–monzonite–syenite intrusions, regionally extensive quartz monzonite to granite, and small leucocratic granite plutons. The U–Pb zircon ages (Brooks, 1983; Kerr and Krogh, 1990; Kerr *et al.*, 1992) are between 1670 and 1630 Ma, but cluster around 1650 Ma. In the south, these rocks have east–west structural trends that were imposed by the Grenvillian Orogeny. There are no reliable field criteria to aid in the distinction of posttectonic Makkovikian and Labradorian suites. However, there appear to be significant compositional differences between the two assemblages.

Unclassified Plutonic Rocks

Several minor units remain unclassified because of difficulties in separating the posttectonic Makkovikian and Labradorian assemblages. The most extensive unclassified units include the foliated granitoid rocks and granitoid gneisses that are prevalent to the south of the Benedict fault zone; these are described separately.

Bruce River Group

The Bruce River Group (Ryan, 1984; Ryan *et al.*, 1987) is a supracrustal sequence in the west (Figure 3), but lies outside the confines of the study area. It rests unconformably upon the Moran Lake Group, and has suffered only minimal (Grenvillian) deformation and metamorphism. It consists of arkose, conglomerate and sandstone, overlain by a thick (8 km) accumulation of mafic to felsic volcanic and pyroclastic rocks. The U–Pb zircon dating (Schärer *et al.*, 1988) indicates an age of ca. 1649 ± 1 Ma, in contrast to previous Rb–Sr ages of ca. 1530 to 1510 Ma (D. Kontak, *in* Ryan, 1984). Thus, it is regarded as a volcanic sequence of equivalent age to the TLGB Labradorian assemblage (after Ryan, 1984; Schärer *et al.*, 1988).

Michael Gabbro Intrusions

Small bodies of mafic intrusive rocks (Michael Gabbro) are widespread in the southern part of the Makkovik Province and adjacent Grenville Province. They consist of olivine–gabbro and gabbronorite emplaced ca. 1425 Ma (U–Pb zircon; Schärer *et al.*, 1986), and have variably developed coronitic structures that record the effects of Grenvillian metamorphism or metamorphic conditions at the time of their emplacement (Gower, 1986). They have not been examined during this project.

Grenville Province Granitoid Gneisses

The Grenville Front Zone is represented in the study area by the Benedict fault zone (Figure 3). The area, south of the fault, is dominated by deformed granitoid rocks and granitoid gneisses with relict porphyritic (i.e., augen) textures and cataclastic fabrics. These are associated with fine-grained, banded, mylonitic rocks. These gneisses are probably reworked equivalents of the granitoid intrusive rocks of the Makkovik Province (Gower and Owen, 1984), but the Makkovikian and Labradorian components cannot be distinguished. The granitoid gneisses are thus described in conjunction with unclassified plutonic rocks. Deformed (variably coronitic) intrusions of the Michael Gabbro are most common south of the Benedict fault zone.

Structural and Metamorphic Patterns

Structural Trends

The structure of the study area has been discussed by Gower *et al.* (1982), Ryan (1984), Clark (1973, 1979) and Marten (1977). It is dominated by two major structural trends (Figure 3). The older trend has a northeast or north-northeast orientation, and is typified by the fold and thrust belt along Kaipokok Bay. This trend is present also in syntectonic Makkovikian plutonic rocks. It represents structures developed during the Makkovikian orogeny at or before ca. 1800 Ma (Gower and Ryan, 1986). Major faults associated with this trend include the slide and thrust zones in the Lower Aillik Group, which appear to reflect the earliest Makkovikian deformational events (Marten, 1977).

The second trend is of broadly east–west orientation, and is probably related to the Grenvillian Orogeny at ca. 1100 to 1000 Ma. The northeast to north-northeast 'Makkovikian trend' and the east to east-northeast 'Grenvillian trend' are distinct in the east and north, but their discrimination becomes more difficult in the southwest, where both trends converge into a general northeast direction (Figure 3). The Grenvillian trend is most strongly developed south of the Benedict fault zone, but several fault zones in the Makkovik Province share its general orientation and, locally, posttectonic Makkovikian and Labradorian plutonic rocks have east-trending foliations.

Major Faults

A number of major east-trending faults divide the area into structural blocks. The most important is the Benedict fault zone, which is the locus of the Grenville Front Zone in the study area (Gower *et al.*, 1980). This is probably a high-angle reverse or thrust fault (Gower, 1981; Owen *et al.*, 1986). The subparallel Adlavik Brook fault zone (Gower *et al.*, 1982) has a transcurrent displacement of about 20 to 30 km. This fault marks the northern limit of sporadic Grenvillian deformation. The area between these two fault zones is characterized by local, strongly foliated to cataclastic areas, oriented subparallel to the major faults. It is dominated by plutonic units and subordinate areas of the Upper Aillik Group. North of the Adlavik Brook fault zone, the Upper Aillik Group is areally dominant, and TLGB plutonic rocks occur as discrete, isolated bodies, many of which appear to represent the roof zones of plutons.

Contrasts across the Benedict and Adlavik Brook fault zones are interpreted to reflect differences in crustal levels imposed by reverse faulting and thrusting during the Grenvillian Orogeny, which exposed progressively deeper levels of the crust in the south (e.g., Gower and Ryan, 1986; Kerr, 1987).

Metamorphism

The principal metamorphic events correspond to the development of Makkovikian and Grenvillian structural trends in the area. Makkovikian metamorphism affected the Archean gneisses, the Aillik Group and the syntectonic Makkovikian plutonic rocks. In the Lower Aillik Group, upper-amphibolite-facies conditions were attained, and pelitic rocks (and basement gneisses) were locally partially melted. The Upper Aillik Group ranges from greenschist to lower-amphibolite facies, with a regional decrease in grade from northwest to southeast (Gower *et al.*, 1982). Syntectonic Makkovikian plutonic rocks are variably recrystallized, but most retain relict igneous mineral assemblages, suggesting that their emplacement postdated the peak of this metamorphism. Grenvillian metamorphism is prevalent south of the Adlavik Brook fault zone, and is manifested by recrystallization, strain, and variable retrogression of igneous mineral assemblages in all components of the TLGB. These effects become stronger within the Grenville Province, but relict igneous textures are locally visible well to the south of the Benedict fault zone.

Contact metamorphic effects associated with plutonic rocks of the TLGB appear minor; this is probably a function of the unreactive quartzofeldspathic compositions of the Upper Aillik Group felsic volcanic rocks that form the dominant country rocks. In areas adjacent to plutonic rocks, these are commonly saccharoidal in texture, suggesting static, thermal recrystallization of quartz and feldspar. Where amphibolitic rocks occur in the country-rock assemblage, skarn-like calc-silicate zones consisting of varied mixtures of calcite, hematite, epidote, diopside and andradite are developed around contact zones.

GEOLOGY AND PETROLOGY

This section contains all of the descriptive geological and petrological information concerning the plutonic rock associations examined. It is subdivided into sections corresponding to the three main subdivisions outlined in the previous section (i.e., the syntectonic Makkovikian plutonic rocks, the posttectonic Makkovikian plutonic rocks and the Labradorian plutonic rocks), with a short section on unclassified plutonic rocks. The geology of the study area is detailed in Map 94-216.

Plutonic associations are divided into a number of units and intrusive suites, for which new, formal names are proposed. The term 'intrusive suite' is used here in two senses. First, it is used to group geographically discrete units that are closely similar in petrology (and geochemistry). In this case, individual units have also been named, e.g., the Bayhead granite is a member of the Strawberry Intrusive Suite. Second, it is used to group units of differing composition that are spatially related and considered to be genetically linked on petrological and/or geochemical grounds. In this case, individual units have generally not been named. There are as yet no firm rules for stratigraphic nomenclature of plutonic rocks, but this usage corresponds with widespread terminology, and with suggestions made by Salvador (1987) and Bateman (1988) to the International Subcommission on Stratigraphic Conventions.

SYNTECTONIC MAKKOVIKIAN PLUTONIC ROCKS

The syntectonic Makkovikian association comprises foliated plutonic rocks that have north to northeast-trending foliations similar in orientation to structural trends within the Aillik Group. They have thus experienced at least the latest period(s) of Makkovikian deformation. The label 'syntectonic' is therefore applied to these rocks. It is recognized, however, that the contrast in deformation state between these rocks and their 'posttectonic' Makkovikian counterparts may reflect heterogenous deformation, rather than significant age differences between them.

Syntectonic Makkovikian plutonic rocks are mostly located in the northwest study area (Figure 4a, b). The most areally extensive units are the Long Island Quartz Monzonite, Kennedy Mountain Intrusive Suite and Melody Granite. Two units in the Kaipokok Bay area (Brumwater and Pitre Lake granites) are of limited extent (Figure 4b), but show critical field relationships with deformed Archean gneisses and supracrustal rocks. Foliated granites also occur locally in the east of the study area (Deus Cape and Manak Island granodiorites), and beyond the eastern limit of the study area. The largest single member of this association is the Island Harbour Bay intrusive suite (Ryan *et al.*, 1983), which intrudes reworked Archean rocks north of Kaipokok Bay, and is largely outside the study area.

Long Island Quartz Monzonite

Definition and Extent

The Long Island Quartz Monzonite, herein formally renamed, forms an elongate body in the Kaipokok Bay area (Figure 4), and was originally termed the 'Long Island gneiss' (Gandhi *et al.*, 1969). It is rarely gneissic, and subsequent workers used the term 'Long Island quartz monzonite' (Gower *et al.*, 1982; Kerr, 1986). Definition and boundaries of the unit remain essentially unchanged from those of Gower *et al.* (1982). Two elongated units of similar material, located immediately south of Post Hill (58°54'N, 59°45'W, Figure 4a), are here grouped with the Long Island Quartz Monzonite unit, following Gower *et al.* (1982).

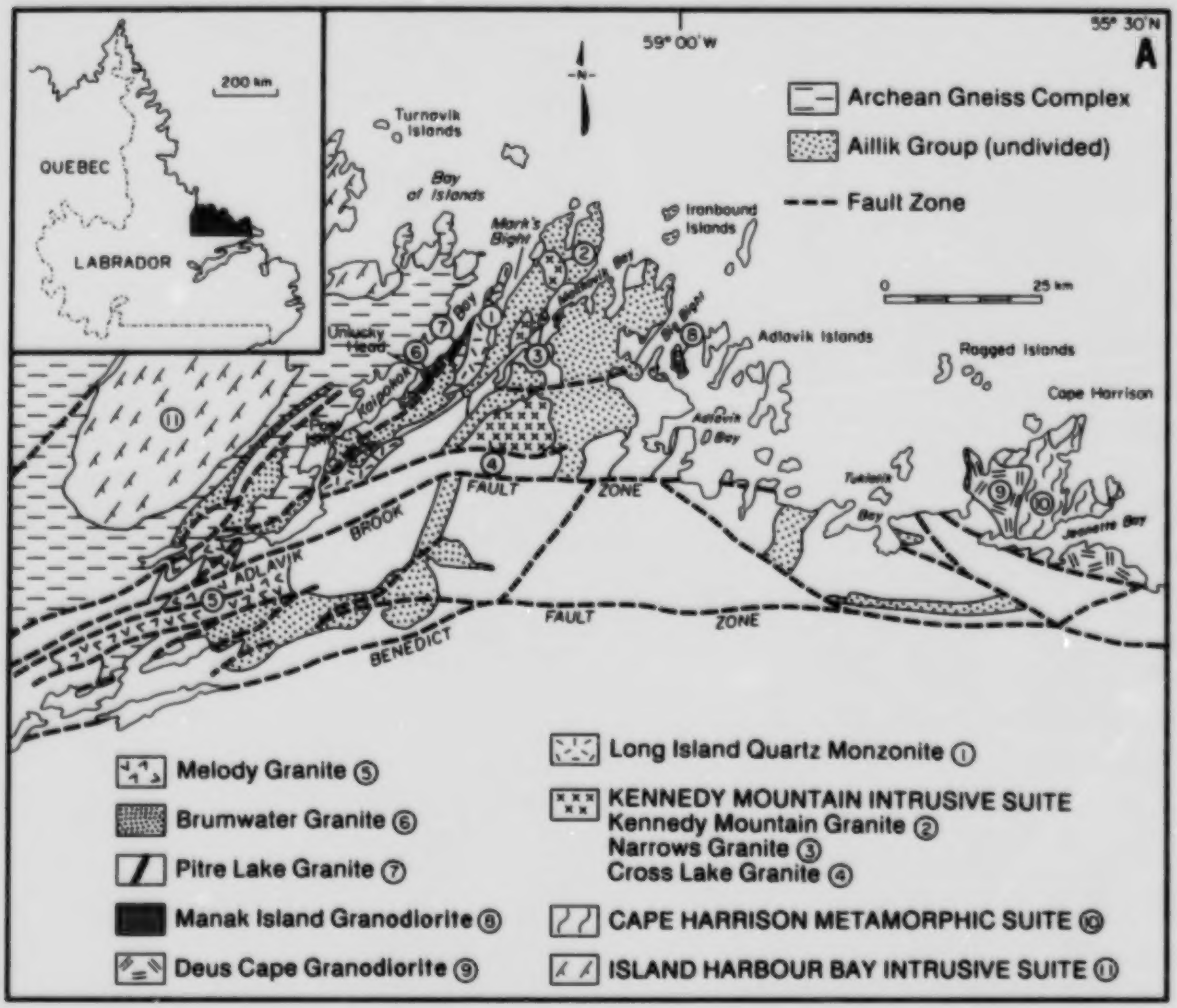


Figure 4. *a) Summary map illustrating the distribution and extent of syntectonic Makkovikian plutonic rocks; b) Geology of part of the eastern side of Kaipokok Bay showing the location and setting of the Brumwater and Pitre Lake granites (after Marten, 1977, and Gower* et al., *1982).*

Description

The Long Island Quartz Monzonite consists of medium-grained, melanocratic, foliated, hornblende–biotite quartz monzonite, granodiorite and (rare) monzogranite. It is characteristically plagioclase-porphyritic, containing small (1 cm) equant phenocrysts. Some features of the unit are illustrated in Plate 1.

In thin section, typical examples contain quartz (10 to 20 percent), microcline (30 to 40 percent), plagioclase (ca. An_{30}; 30 to 40 percent), hornblende and biotite (subequal; 10 to 25 percent in total), and minor epidote, iron oxide, sphene, apatite, zircon and allanite. The groundmass quartz and feldspar is generally recrystallized, but original plagioclase phenocrysts are commonly well preserved in the least deformed variants, although their edges may be partly recrystallized. They are variably saussuritized and locally display zonation, probably of igneous origin.

A penetrative fabric is strongly developed around the margins of the unit, but parts of the interior appear massive. In thin section, this foliation is defined by alignment of biotite and hornblende; these minerals form aggregates (probably recrystallized versions of larger igneous crystals), associated with sphene, epidote and chlorite in deformed examples. Locally, very strongly deformed variants have a banded or schlieric 'gneiss-like' appearance. Parts of the unit, notably on the east shore of Mark's Bight (55°04'N, 59°24'W; Figure 4a), contain deformed enclaves of a melanocratic phase with a composition that approximates quartz diorite. The banded

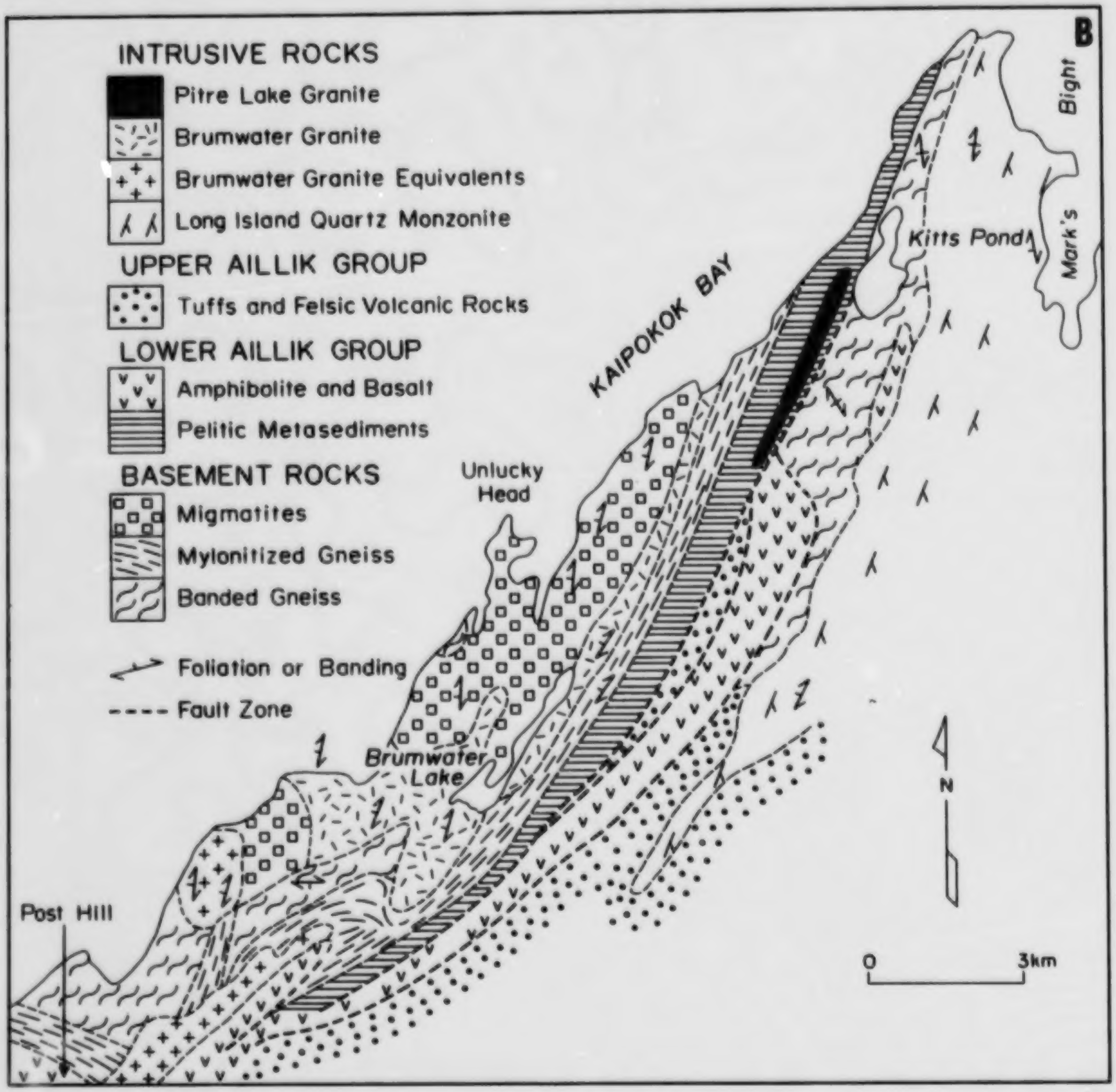


Figure 4. *b) Geology of part of the eastern side of Kaipokok Bay, showing the location and setting of the Brumwater and Pitre Lake granites (after Marten, 1977, and Gower* et al., *1982).*

variants may represent intense deformation and transposition of original textures of this type.

Age

Marten (1977) stated that the unit truncates early (S_1 and S_2) fabrics in surrounding Archean and Aillik Group units, and considered the foliation to be a relatively late (D_3) feature. In the area around Mark's Bight, the unit is disrupted and net-veined by the Duck Island granite of the Monkey Hill Intrusive Suite indicating an age of greater than 1640 Ma.

The Long Island Quartz Monzonite has been dated at 1832 ± 58 Ma by K–Ar whole-rock methods (Gandhi *et al.*, 1969) and at 1802 $^{+13}_{-7}$ Ma by U–Pb zircon methods (Kerr *et al.*, 1992). The latter sample also yielded a U–Pb sphene (titanite) age of 1746 ± 2 Ma, which provides a minimum age for deformation and metamorphism of the unit.

Kennedy Mountain Intrusive Suite

Definition and Extent

This is a new name, formally introduced, for several discrete bodies of closely similar, foliated, leucocratic granitic

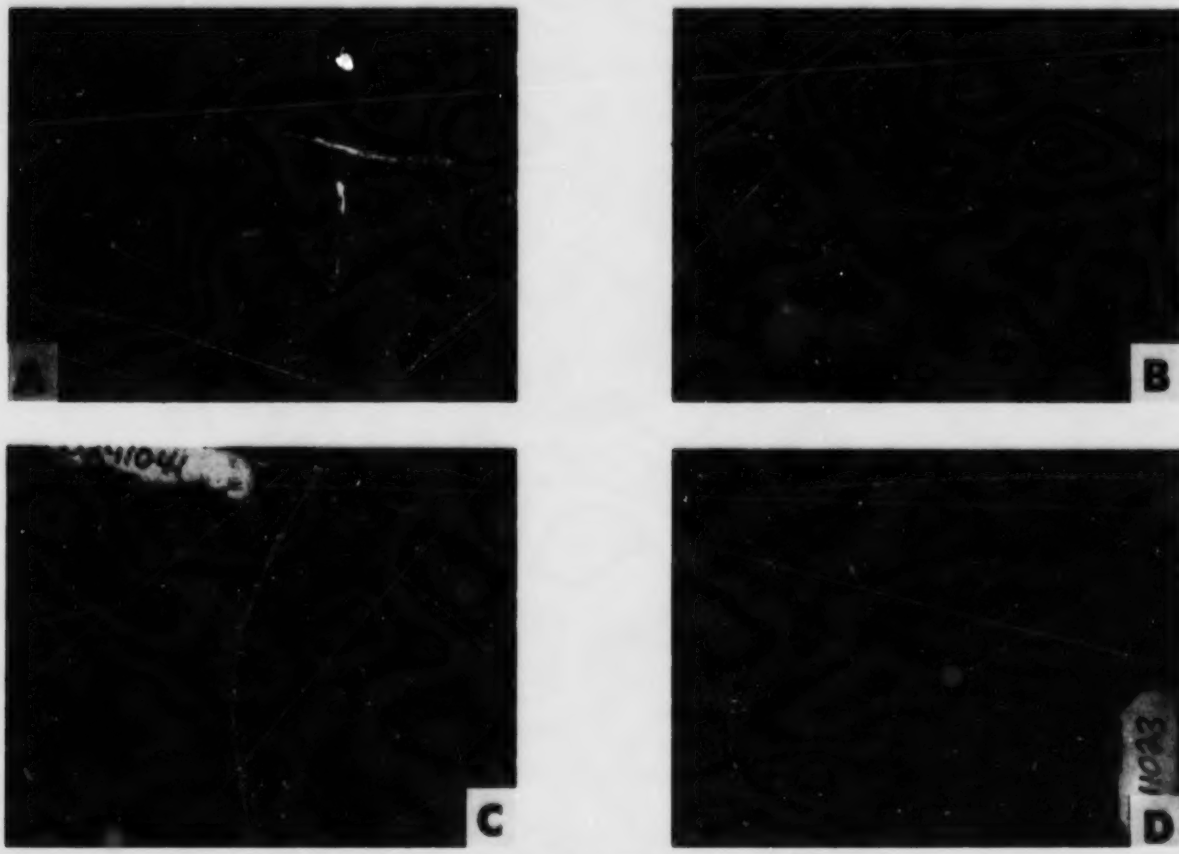


Plate 1. *Features of the Long Island Quartz Monzonite. a) Dioritic inclusions (deformed) in grey quartz monzonite, Mark's Bight. b) Typical weathered surface with plagioclase phenocrysts, Mark's Bight. c) Massive quartz monzonite from centre of body (phenocrysts about 0.5 cm diameter). d) Strongly deformed variant from eastern margin of body. All slabs were stained to turn K-feldspar yellow.*

rocks in the Makkovik Bay area (Figure 4). These include units 17a and 17c of Gower *et al.* (1982), and similar foliated granitoid rocks outlined by Kerr (1986, 1987). The type unit (Kennedy Mountain granite) corresponds to the Kennedy's Cove 'gneiss' of Clark (1973), but it is very rarely gneissic. The name is taken from an informal name for the prominent topographic high produced by this unit opposite Makkovik Harbour.

Description

The suite is dominated by foliated, variably K-feldspar porphyritic, monzogranite, granite and alkali-feldspar granite, commonly containing accessory fluorite. Some features of the suite are illustrated in Plate 2. In the field, all component units of the suite are similar in appearence, consisting of white, pink or buff-weathering, generally medium- to coarse-grained material. Subordinate fine-grained, equigranular granite occurs locally in all units, but is particularly abundant in the Cross Lake granite. Foliations are most obvious in relatively melanocratic, porphyritic variants (where they are defined by mafic minerals), whereas equigranular and leucocratic variants commonly appear massive and unfoliated. The fine-grained rocks develop an extremely good glacial polish on hilltops. Coarse-grained, fluorite and/or pyrite-bearing pegmatite veins (locally containing amazonite, a green variety of K-feldspar) intrude many outcrops, particularly in the Cross Lake granite. Xenoliths of country rocks are rare except adjacent to contacts; cognate xenoliths (normally darker than their host) occur locally. The Cross Lake granite appears to be more leucocratic than other units of the suite, and is locally alaskitic (i.e., a fine-grained rock consisting essentially of quartz and alkali-feldspar; Johannsen, 1920).

In thin section, typical examples consist of quartz (15 to 35 percent), microcline (25 to 60 percent), plagioclase (An_{20-30}; 10 to 50 percent), biotite and hornblende (1 to 15 percent of total, generally less than 5 percent; biotite dominant), sphene (up to 2 percent), fluorite (up to 1 percent) and prominent accessory zircon, apatite, allanite and iron oxides. Most examples contain both hornblende and biotite, but leucocratic variants are hornblende-poor or hornblende-free. Purple fluorite is widespread (particularily in leucocratic rocks), and forms coarse patches along foliation planes. Most

Plate 2. *Features of the Kennedy Mountain Intrusive Suite. a) Coarse-grained monzogranite (Narrows granite, Makkovik Bay). b) Fine-grained alaskitic variant of the Cross Lake granite; the superb glacial polish is a reflection of the pervasive recrystallization, which reduces the natural tendency of granite to disaggregate. c) Fluorite-bearing leucogranite (Kennedy Mountain granite, Makkovik Bay), foliation is parallel to slab label. d) Coarse-grained biotite–hornblende granite (Narrows granite), section cut normal to foliation. e) Fine-grained potassic leucogranite (Cross Lake granite). All slabs were stained to turn K-feldspar yellow.*

examples are recrystallized, particularly in the groundmass, but original igneous textures (K-feldspar phenocrysts and, more rarely, interstitial quartz) are variably preserved. Fine-grained variants generally show strong recrystallization, and

locally have a saccharoidal texture. Mafic minerals and sphene form coarse aggregates, associated with prominent and abundant zircon, allanite, apatite and fluorite crystals. Chlorite and/or epidote are locally important as alteration products of hornblende and biotite.

Anomalous rock types consisting almost entirely of sodic plagioclase (< An_{15}) and quartz are present locally within all units of the Kennedy Mountain Intrusive Suite. These are considered to be Na-metasomatized, rather than original, compositions, as they show geochemical evidence of major- and trace-element disturbance. Rare albite rims or patches on K-feldspar phenocrysts in 'normal' variants form the only petrographic evidence for this process; the anomalously sodic rocks are thoroughly recrystallized.

Age

The Kennedy Mountain granite and Narrows granite intrude the Upper Aillik Group, but are cut by the Labradorian Monkey Hill Granite, dated at ca. 1640 Ma (Kerr *et al.*, 1992). This indicates a minimum age of 1640 Ma. Units assigned to the suite contain a single northeast-trending foliation; by analogy with the Long Island Quartz Monzonite unit, this is interpreted to be a D_3 feature resulting from Late Makkovikian deformation, and implies a similar age of ca. 1800 Ma; the unit is not dated reliably. Gandhi *et al.* (1969) obtained a K–Ar (mixed hornblende and biotite) age of 1531 ± 38 Ma from the Kennedy Mountain granite, which is probably anomalously young. No U–Pb geochronological data are available.

Melody Granite

Definition and Extent

The new name Melody Granite is formally introduced for an elongate unit of strongly foliated granitoid rocks in the western part of the study area (Figure 4a). It corresponds to parts of unit 14 of Bailey (1979) and parts of Unit 27 of Gower *et al.* (1982). Ryan (1984) grouped it with his units 23 and 24, based on compilation from unpublished BRINCO maps.

Description

The unit is dominated by pink to brick-red, K-feldspar-rich granodiorite, granite and alkali-feldspar granite. Strong deformation (relative to the Long Island Quartz Monzonite and the Kennedy Mountain Intrusive Suite) is characteristic of much of the unit. Some features of the unit are illustrated in Plate 3. It has a widely developed cataclastic to protomylonitic fabric and commonly shows augen texture. Strong hematization of K-feldspar phenocrysts is common in many areas. There are two textural variants, defined by variation in total mafic mineral content. The melanocratic variants commonly show more obvious relict porphyritic textures, but leucocratic variants are also strongly K-feldspar porphyritic where weakly deformed. The distribution of these two variants corresponds generally to units 23 and 24 of Ryan (1984), described as granite and granodiorite, respectively. No sharp contacts between these were observed in this study, and similar gradational variations may be seen within the confines of single outcrops. They are considered to be gradational 'facies' and are not separated on the geological maps.

In thin section, the Melody Granite consists of quartz (15 to 40 percent), microcline (30 to 65 percent), plagioclase (An_{20-30}; 20 to 40 percent), biotite, chlorite, epidote and sphene (2 to 7 percent in total), hornblende (relict, normally less than 1 percent) and accessory allanite, zircon and (rare) fluorite. Most examples are strongly recrystallized, and have a granular texture. Many examples contain quartz and feldspar ribbons, which are oriented parallel to microcrystalline mylonitic zones. The mafic mineral assemblage varies with the intensity of deformation and metamorphism; weakly deformed samples contain aggregates of fine-grained green-brown biotite and local relict hornblende, whereas strongly deformed variants contain only sphene–chlorite–epidote aggregates along foliation planes.

Age

The contact relations of the Melody Granite are unknown, as most of its boundaries correspond with inferred fault zones or areas of very poor exposure. The Melody Granite is undated. Ryan (1984) mapped it as continuous with his Unit 23, based on compilation of unpublished BRINCO descriptions. Ryan's Unit 23 has yielded an age of 1910 ± 10 Ma about 50 km west of the study area (Gandhi *et al.*, 1988; revised to 1891 ± 5 by Kerr *et al.*, 1992). This is significantly older than most ages obtained from Makkovikian granitoid rocks, and may indicate a different affinity for this unit; however, the correlation is based on lithology, and may not be reliable. For the purposes of the current discussion, therefore, the Melody Granite is regarded as a syntectonic Makkovikian intrusion.

Brumwater Granite

Definition and Extent

The Brumwater granite (Marten, 1977) is a small, tabular body that intrudes reworked Archean basement rocks southeast of Kaipokok Bay (Figure 4b). It was defined and mapped by Marten (1977), and visited only briefly during this project. Marten (1977) describes similar rock types from other parts of the Archean inlier along Kaipokok Bay, which he correlated with the Brumwater granite (Figure 4b).

Description

The unit consists of grey to pink, medium- to coarse-grained, foliated, leucocratic, biotite-granodiorite and monzogranite. It contains inclusions of quartzofeldspathic gneisses, and commonly has a 'nebulitic' or banded appearance. Some features of the unit are illustrated in Plate 4. In thin section, typical examples consist of quartz (15 to

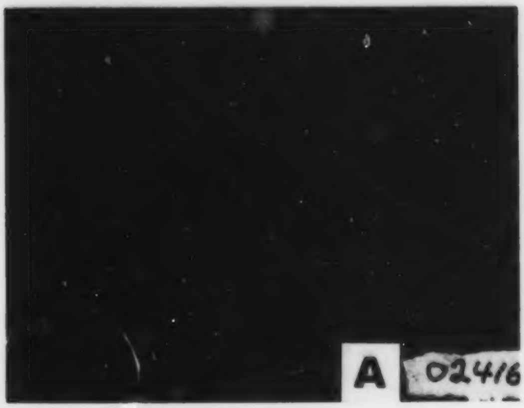


Plate 3. *Features of the Melody Granite. a) Strongly deformed granitoid with ribbon quartz and cataclastic texture, but with relict K-feldspar phenocrysts. b) Weakly deformed, porphyritic, melanocratic variant. All slabs were stained to turn K-feldspar yellow.*

Plate 4. *Features of the Brumwater granite. a) Vein of grey granite cutting refoliated Archean gneiss, Kaipokok Bay area. Note that vein truncates banding, but is affected by later deformation, and shares the same general fabric. b) Typical stained slab, showing heterogeneous and slightly banded appearance of many examples.*

30 percent), microcline (25 to 40 percent), plagioclase (An_{25}; 25 to 40 percent), biotite (2 to 7 percent), muscovite (rare), and accessory allanite and zircon. Recrystallization is pervasive, and foliations are defined by biotite aggregates and concordant pegmatoid seams.

Age

Marten (1977) described a gradational relationship between this unit and adjacent migmatized Archean gneisses in the Unlucky Head area (54°58'N, 59°30'W, Figure 4), and suggested that it may be an anatectic melt derived from them. Enclaves of gneissic material are locally present, and a 'ghost layering' is present in some outcrops. The granite truncates layering in refoliated Archean gneisses that is considered to be a composite S_1/S_2 structure, and the foliation in the granite is thus considered to be a D_3 feature (Marten, 1977). Its chronological relationship to deformation is therefore analogous to that of the Long Island Quartz Monzonite. Schärer *et al.* (1988) obtained a U–Pb monazite age of 1794 ± 2 Ma from a biotite leucogranite that cuts migmatites considered by Marten (1977) to be gradational with the Brumwater granite; this provides a lower limit on the age of the unit. An attempt to date the granite itself failed due to a highly discordant, U-rich zircon population (U. Schärer, personal communication to R.J. Wardle). I. Ermanovics (personal communication, 1991) has suggested that the granite might be Archean, but this conflicts with field relationships indicating that it cuts a migmatitic foliation that affects Proterozoic Kikkertavak Dykes north of Kaipokok Bay (Ryan *et al.*, 1983).

Pitre Lake Granite

Definition and Extent

The Pitre Lake granite, defined and mapped by Marten (1977), is a thin, tabular, subconcordant body that is confined

to metasedimentary rocks of the Lower Aillik Group in the Kitts Pond area (Figure 4b). It was visited only briefly during this study.

Description

The unit consists of medium-grained, white- to pale-pink or buff, equigranular, biotite–muscovite granite. It is generally homogeneous, but locally has a ghost layering, which locally defines complex folding. Some features of the unit are illustrated in Plate 5. It contains inclusions of metasedimentary material that resemble its country rocks; the folded layering may be an inherited feature, rather than a result of post-intrusion deformation. Amphibolitic xenoliths were also observed. In thin section, it consists of quartz (20 to 30 percent), microcline (30 to 60 percent), plagioclase (An_{20-30}; 20 to 30 percent), muscovite and biotite (5 to 10 percent in total, muscovite dominant).

Age

The granite truncates the foliation in the host metasediments (a composite D_1/D_2 structure; Marten, 1977; Gower *et al.*, 1982), but contains a weak to moderate foliation subparallel to or slightly oblique to its contacts. Marten (1977) considered this to be a D_3 feature, and suggested that the unit was a syn-D_3 intrusion, which implies a similar age to other syntectonic Makkovikian units in the Makkovik Bay area. No geochronological data are available from the unit.

Manak Island Granodiorite

Definition and Extent

This unit is located near Adlavik Bay (Figure 4a), and was previously grouped with the Cape Strawberry granite by Doherty (1980) and Gower *et al.* (1982). It is, however, lithologically distinct from the latter in all respects and has a north-trending foliation, which is not present in surrounding units. The unit forms a narrow zone between gabbro and diorite of the Adlavik Intrusive Suite and adjacent monzonite and quartz monzonite of the Numok Intrusive Suite. These surrounding units are massive and undeformed, and the Manak Island unit probably represents a screen between younger intrusions.

Description

The unit consists of white to grey, medium- to coarse-grained, foliated granodiorite and monzogranite. Some features of the unit are illustrated in Plate 6. The unit resembles the more homogeneous variants of the Brumwater granite, but is generally free of xenoliths and ghost layering. A weak to moderate north-trending foliation is defined by alignment of mafic mineral aggregates.

In thin section, typical examples consist of quartz (15 to 20 percent), microcline (20 to 40 percent), plagioclase (An_{25-35}; 40 to 60 percent), biotite (5 percent), and accessory sphene, apatite and (rare) allanite and zircon. Most samples are variably recrystallized to a polygonal mosaic, although scattered microcline and (locally) zoned plagioclase phenocrysts are preserved.

Age

The Manak Island granodiorite is intruded by gabbro and diorite of the Adlavik Intrusive Suite on the adjacent mainland, but the nature of contacts with the Numok Intrusive Suite and the Upper Aillik Group at the southern end of Manak Island is unknown. No geochronological data are available from the unit, but undeformed rocks of the adjacent Numok Intrusive Suite have given a U–Pb zircon age of 1801 $\pm$ 2 Ma. (Kerr and Krogh, 1990; Kerr *et al.* 1992). If these differences in deformation state truly indicate differences in age, this provides a lower limit for the age of the Manak Island granodiorite.

Deus Cape Granodiorite

This unit occurs in the extreme east of the study area, adjacent to the Cape Harrison Metamorphic Suite (Gower, 1981). It has been visited only in a few localities during this project, and the following description is partially adapted from Gower (1981). The unit consists of coarse-grained, pink to grey, foliated, K-feldspar megacrystic to seriate granodiorite.

Contact relations are unknown, but the unit displays a single north-northeast-trending foliation, and contrasts with the adjacent polydeformed migmatitic rocks of the Cape Harrison Metamorphic Suite (Gower, 1981). This contrast suggests that it occupies a time slot between the Cape Harrison Metamorphic Suite and undeformed Makkovikian plutonic rocks. Kerr and Krogh (1990) and Kerr *et al.* (1992) report a U–Pb zircon age of 1837 $^{+6}_{-4}$ Ma from this unit. This age is slightly older than the ca. 1800 Ma ages recorded from the Long Island Quartz Monzonite (Kerr *et al.*, 1992), parts of the Island Harbour Bay intrusive suite (Loveridge *et al.*, 1987) and other Makkovikian intrusions in the study area. At the present time, the Deus Cape granodiorite is the oldest recognized syntectonic Makkovikian intrusion. The age also provides a minimum age for the Cape Harrison Metamorphic Suite, which is the only candidate for 'basement' material in the east of the area.

Island Harbour Bay Intrusive Suite

The Island Harbour Bay intrusive suite (Ryan *et al.*, 1983) lies mostly outside the study area (Figure 4a), but, as the largest single Makkovikian plutonic body, merits some general discussion here. The suite was examined in only a few localities during this project; the following outline is taken from Ermanovics *et al.* (1982), Ryan *et al.* (1983) and I. Ermanovics (personal communication, 1988).

The suite includes a wide variety of rock types that display complex field relationships. Ryan *et al.* (1983) divided it into a grey tonalite to granodiorite, and a homogeneous

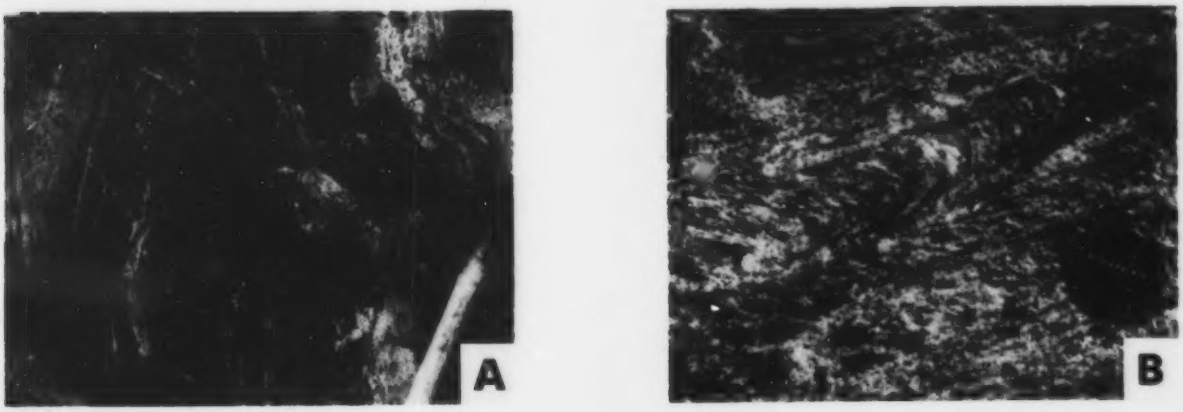


Plate 5. *Features of the Pitre Lake granite. a) Part of a concordant metasedimentary inclusion (centre) within the granite, which is the white material to left and right. b) Complexly folded 'ghost' layering, possibly inherited from the metasedimentary protolith.*

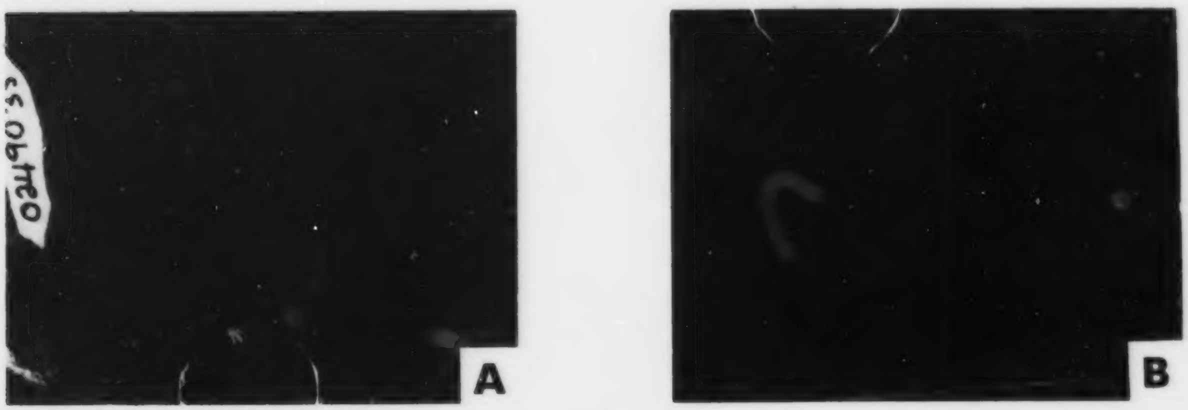


Plate 6. *Features of the Manak Island granitoid. a) and b) Typical stained slabs of weakly foliated, leucocratic monzogranite. (Foliation is not obvious in slabs, but is easily recognized on outcrop surfaces (field observation)).*

pink granite. The former is more abundant and forms the outer part of the intrusion; it is compositionally varied, inclusion-rich and polyphase. Ryan *et al.* (1983) distinguish diorite, quartz diorite, K-feldspar megacrystic granodiorite, and leucocratic granite, all of which show mutually intrusive relationships suggesting synchronous emplacement. The central granite unit lacks this complexity, and is commonly inclusion-free. It consists of pink to grey, feldspar porphyritic, locally megacrystic, biotite granite, locally containing interstitial fluorite. All of the above phases are intruded by pegmatite and aplite dykes.

The contact between outermost tonalite-granodiorite and Archean gneisses is described by Ryan *et al.* (1983) as a complex *lit-par-lit* migmatite zone, where foliations in the granitoid rocks are parallel to those in the gneisses. Early foliated granitoid dykes are cut by later undeformed phases, indicating syn- to posttectonic emplacement. Foliations in the outer parts of the intrusion are locally cataclastic to mylonitic, and have concentric structural trends (Ryan *et al.*, 1983). Rafts of Archean gneiss within this marginal zone display the strong 'straightened' layering associated with early Makkovikian deformation (Ryan and Kay, 1982). The central portion of the body, in particular the granite unit, is massive to weakly foliated, and appears posttectonic.

The Island Harbour Bay intrusive suite has been dated by a variety of methods. U–Pb zircon data from the dominant grey granodiorite (Loveridge *et al.*, 1987) suggests an age of 1805 ± 5 Ma, similar to that of the Long Island Quartz Monzonite. This agrees well with Rb–Sr ages of 1805 ± 42 for the granite unit, and 1843 ± 90 Ma and 1794 ± 71 Ma for the tonalite–granodiorite unit (Grant *et al.*, 1983). An U–Pb zircon age of 1973 ± 15 Ma (Brooks, 1982) from the tonalite unit is enigmatic. It may reflect inheritance, but there is no evidence of inclusions in outcrop (B. Ryan, personal communication, 1988), and no cores are reported from the zircons. Ermanovics (personal communication, 1988)

considers the ca. 1800 Ma ages from the granite unit to be minimum ages only, and states that the tonalitic rocks may be somewhat older. As will be shown later, these tonalitic and trondhjemitic compositions are not typical of the Makkovikian plutonic assemblage in the study area.

POSTTECTONIC MAKKOVIKIAN PLUTONIC ROCKS

This association comprises mainly undeformed plutonic rocks. There are few field criteria to separate these from similarly undeformed Labradorian plutonic rocks and this association is presently defined primarily by geochronological data. As discussed previously, 'posttectonic' is partly a label of convenience; it does not necessarily mean that these rocks are significantly younger than the 'syntectonic' Makkovikian association; in fact, U–Pb geochronological data (Kerr and Krogh, 1990; Kerr *et al.*, 1992, also see below) suggest a close similarity in age between many examples. The term also does not imply a universal absence of foliations; in the south these rocks locally display evidence of deformation. However, the predominance of east-trending fabrics (parallel to faults defining Grenville Front Zone) in such areas suggests that these represent Grenvillian, rather than Makkovikian, deformation.

Posttectonic Makkovikian plutonic rocks are subdivided into three intrusive suites and three ungrouped units (Figure 5). The Numok Intrusive Suite ranges in composition from monzodiorite to quartz syenite, but is dominated by quartz monzonite. The Strawberry Intrusive Suite includes several plutons of distinctive fluorite-bearing granite. The Lanceground Intrusive Suite consists of three quartz syenite to granite plutons that locally show hypersolvus characteristics. The Big River Granite is an extensive body of porphyritic granite that shows distinctive mantled feldspar ('pseudorapakivi') textures. Other units comprise the Freshsteak and Noarse Lake granitoids (probably equivalent), and the Stag Bay granodiorite. Until recently, the latter were grouped with unclassified plutonic rocks by Kerr (1989a).

Numok Intrusive Suite

Definition and Distribution

This is a new, formal name introduced for monzonite, quartz monzonite, syenite and quartz-syenite exposed in two areas referred to below as the northern and southern zones (Figure 5). The northern zone is restricted mostly to the Adlavik Islands, and the southern zone is located in an inland area south of the Adlavik Brook fault zone. The name is derived from the local name for Kikkertavak Island, which is unsuitable as it is also used for Proterozoic dykes elsewhere in Labrador (Ryan *et al.*, 1983). The Numok Intrusive Suite in the northern zone was previously grouped with the Adlavik Intrusive Suite by Kerr (1986, 1987), because they resemble some of its more differentiated variants. The southern zone was mostly undivided by Gower *et al.* (1982). U–Pb geochronological data, however, indicate that there is no link between these rocks and the Labradorian Adlavik Intrusive Suite. The northern and southern zones of the Numok Intrusive Suite are interpreted as disrupted halves of an originally continuous pluton, cut by the transcurrent Adlavik Brook fault zone. Three compositional units (not named) are defined within the suite, and are described below in order of abundance.

Monzonite and Quartz Monzonite

Definition and Extent. In the northern zone, this unit corresponds broadly with Unit 23 of Gower *et al.* (1982); in the southern zone, it is a new subdivision of their regionally extensive Unit 26.

Description. The unit is dominated by homogeneous, white, grey or pink, coarse-grained biotite–hornblende monzonite, quartz monzonite and (locally) syenite to quartz syenite. Some features of the unit are illustrated in Plate 7. It is commonly seriate to porphyritic, with phenocrysts of both K-feldspar and plagioclase, ranging up to 2 cm maximum dimension. K-feldspar phenocrysts are commonly more abundant and larger than plagioclase phenocrysts, and the latter are locally absent altogether. The presence of coarse, euhedral hornblende and biotite is particularly characteristic. Excluding a complex zone along its western margin, the unit is undeformed and homogeneous in both northern and southern zones, is generally inclusion-poor (although it contains sporadic gabbroic blocks) and consistent in both mineralogy and texture.

In thin section, typical examples consist of quartz (5 to 20 percent), microcline (30 to 50 percent), plagioclase (An_{30-40}; 30 to 50 percent), hornblende and biotite (5 to 25 percent, subequal), clinopyroxene (up to 5 percent, commonly relict) and minor sphene, zircon, iron oxide, allanite, apatite and fluorite. In the northern zone, original igneous textures are exceptionally well preserved; for example, interstitial quartz crystals are clearly visible, and perthitic textures widely developed in K-feldspar. Clinopyroxene, where present, commonly forms ragged inclusions in amphibole crystals. Most examples from the southern zone are similarly well preserved; however, a few areas (notably in the south) show minor shearing and recrystallization.

Field Relationships and Age. In the northern zone, on the Adlavik Islands, this unit appears to be gradational to the east with adjacent syenite and quartz syenite. The western boundary of the unit in the north consists of a complex agmatite zone up to 1 km wide, best exposed near the mouth of Adlavik Bay. The northern part of this zone comprises grey-brown quartz monzonite containing numerous stoped blocks of diabase, gabbro, leucogabbro and porphyritic diorite, some of which display cumulate layering. A fabric around some of the larger inclusions is probably a flow feature, as the inclusions themselves are undeformed. On the south shore of Adlavik Bay, less than 1 km along strike, the same agmatite has a north-trending foliation, present also in the mafic inclusions, which are here transformed to amphibolite. This

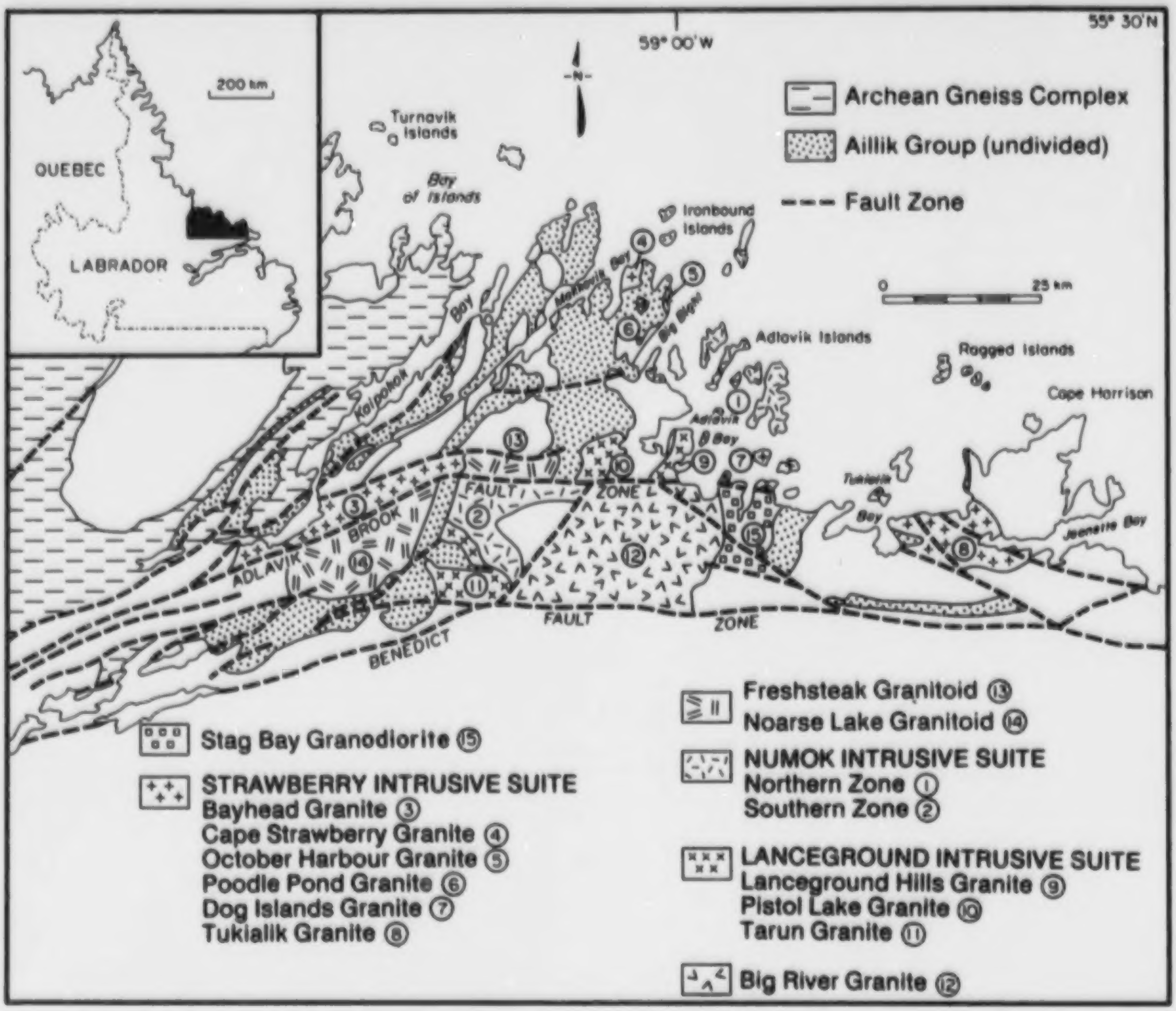


Figure 5. *Summary map illustrating the distribution and extent of posttectonic Makkovikian plutonic units.*

complex zone was previously interpreted in terms of forcible emplacement of quartz monzonite into gabbro and diorite of the adjacent Adlavik Intrusive Suite (Gower, 1981; Gower *et al.*, 1982; Kerr, 1986). However, U–Pb ages from the agmatite neosome at Adlavik Bay show crystallization at 1801 ± 2 Ma (Kerr and Krogh, 1990; Kerr *et al.*, 1992), indicating that the mafic inclusions are older than 1800 Ma, and are hence unrelated to the nearby Adlavik Intrusive Suite, dated at 1649 ± 1 Ma (Kerr and Krogh, 1990; Kerr *et al.*, 1992). The fabric in the deformed part of the zone may result from syn-emplacement deformation at the original margin of the Numok Intrusive Suite, or may be associated with emplacement of the adjacent Adlavik Intrusive Suite. As the foliation affects both paleosome and neosome in the agmatite, it must be younger than 1801 Ma. The foliation is of local extent only, as it dies out quickly to the north. On Kikkertavak (Numok) Island, the quartz monzonite is cut by two dykes (up to 10m wide) of quartz-feldspar porphyry that resembles the adjacent Dog Islands granite, assigned to the Strawberry Intrusive Suite.

Syenite and Quartz Syenite

Definition and Extent. This unit occurs on the outer Adlavik islands, but is most extensively exposed in the southern zone. In the north, it corresponds generally with Unit 31 of Gower *et al.* (1982), and in the south, partly with the 'Tarun Syenite' of Gandhi *et al.* (1969) and Gower *et al.* (1982; Unit 26c). Similar rocks occur on the Ragged Islands (Gower, 1981), suggesting that it may also be regionally extensive in the north.

Description. This unit is dominated by pink, brown or grey-green, coarse grained, K-feldspar porphyritic, pyroxene–biotite–hornblende syenite, quartz syenite and alkali-feldspar syenite with interstitial quartz and mafic phases. Some features of the unit are illustrated in Plate 8. Distinctive blue-

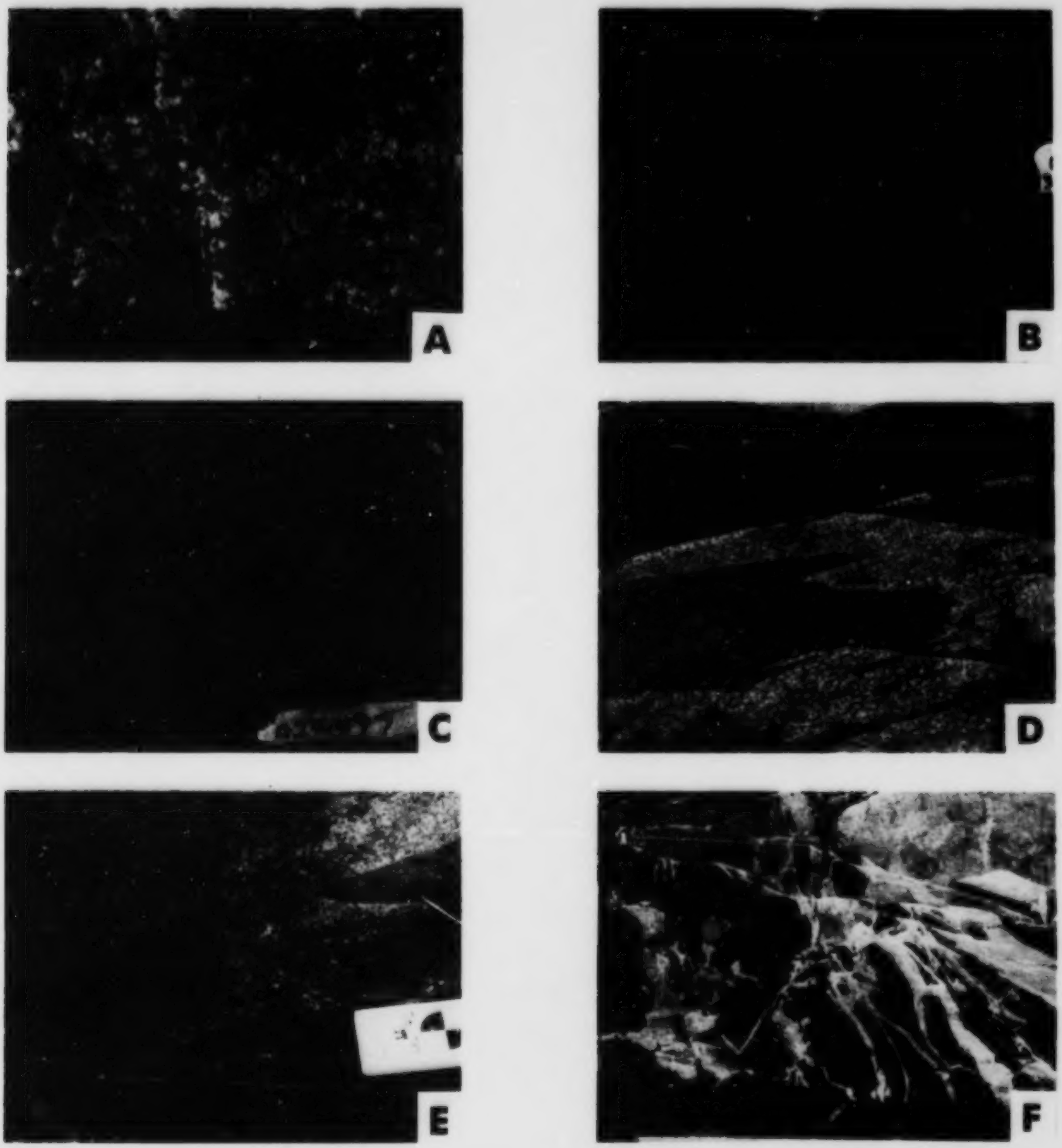


Plate 7. *Features of the Numok Intrusive Suite (monzonite–quartz monzonite unit). a) Typical homogeneous quartz monzonite, Long Tickle Island. b) Porphyritic variant, same area. c) Typical example with part of cognate xenolith, Big River area. d) Undeformed agmatitic border zone, north side of Adlavik Bay, e) Flow fabric around mafic xenolith in agmatite. f) Foliated agmatite cut by later fine-grained granitoid material, south side of Adlavik Bay. Slabs are stained for K-feldspar.*

grey quartz occurs in the northern zone. Intense weathering to a yellow-brown gravel is characteristic of it in many areas, particularly on the Adlavik Islands. The southern zone displays variable recrystallization and deformation, particularly in areas close to the Adlavik Brook fault zone.

In thin section, typical examples consist of quartz (up to 15 percent), K-feldspar (40 to 80 percent), plagioclase (up to 30 percent, excluding perthite lamellae in K-feldspar), clinopyroxene, hornblende and biotite (5 to 25 percent in total), fayalite (relict, normally 2 percent or less), prominent

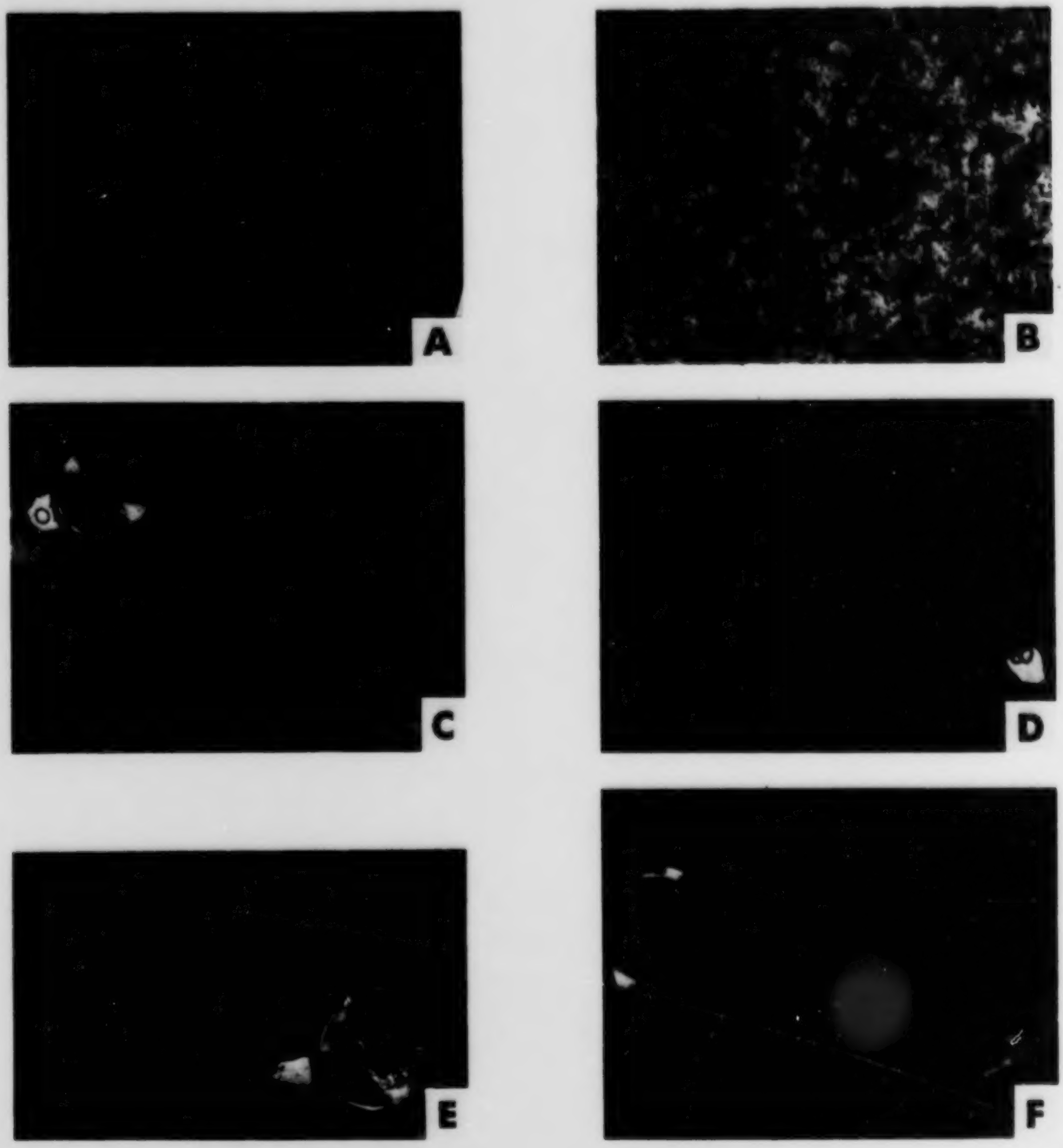


Plate 8. *Features of the Numok Intrusive Suite (syenite—quartz syenite unit. a) Homogeneous syenite, Dunn Island. b) Coarse-grained quartz syenite, north of White Bear Mountain. c) Hypersolvus, K-feldspar-porphyritic, fayalite-pyroxene syenite, Cape Kitchener. d) Quartz syenite, Kikkertavak Island. e) Fine-grained phase in same general area. f) Coarse-grained syenite with ovoidal phenocrysts and weak deformation, north of White Bear Mountain. Slabs are stained for K-feldspar.*

zircon, and minor apatite, sphene and iron oxide. Igneous textures are well preserved in the northern zone; both quartz and mafic minerals display an interstitial habit. K-feldspar phenocrysts consist of coarse perthite, with relict simple twinning suggesting that they are microcline pseudomorphs after orthoclase. Plagioclase (excluding that in perthite) is rare or absent; many variants appear to be of hypersolvus origin. Both clinopyroxene and biotite are iron-rich,

displaying distinctive green and red-brown colours, respectively. Fayalitic olivine, commonly relict and extensively altered to iron oxide-hydroxide ('iddingsite') is an important and diagnostic minor phase. Patches of this material in other samples are probably pseudomorphs after fayalite. The intense weathering is probably related to the former presence of fayalite; similar effects are widespread in fayalite-bearing rapakivi granitoid rocks elsewhere in Labrador (Hill, 1982; B. Ryan, personal communication, 1988). Much of the hornblende appears to be late-magmatic or post-magmatic after clinopyroxene, which locally forms cores in amphibole crystals. Undeformed examples from the southern zone are similar to those from the type area.

Age and Field Relationships. Massive fayalite-bearing syenite from Kikkertavak (Numok) Island has given a concordant U–Pb zircon age of 1801 ± 2 Ma (Kerr and Krogh, 1990; Kerr *et al.*, 1992). The age is closely similar to that from quartz monzonite at Adlavik Bay. As far as can be ascertained, the contact between the two units appears to be gradational in the Adlavik Islands. The relationship between syenite in the southern zone and the Upper Aillik Group is unknown, but the syenite is presumed to be younger than the supracrustal rocks.

Plagiophyric Monzodiorite and Monzonite

Definition and Extent. This unit is sandwiched between the quartz monzonite and quartz syenite units in the southern zone of the Numok Intrusive Suite. Contact relationships with surrounding units are unknown. Similar rocks occur locally within the quartz monzonite of the northern zone, but do not form mappable units at the scale of this project. The unit corresponds to part of the regionally extensive Unit 26 of Gower *et al.* (1982).

Description. This unit consists of distinctive, grey to brown, coarse-grained, plagioclase-porphyritic, pyroxene–hornblende monzodiorite and monzonite. Some features of the unit are illustrated in Plate 9. Textures in many samples are of 'cumulate' aspect, and the mafic minerals commonly show an oikocrystic habit. Fresh variants are augite (± hypersthene)–biotite monzonites having minor amphibole, but altered variants dominated by saussuritized plagioclase and fine-grained actinolite are more common. The unit is probably a mafic variant of the monzonite to quartz-monzonite unit, which is locally plagioclase-porphyritic. The rounded, zoned plagioclase phenocrysts impart a distinctive texture in both hand specimen and thin section.

Strawberry Intrusive Suite

Definition and Distribution

Strawberry Intrusive Suite is a new, formal name proposed for several discrete plutons scattered over an east–west distance of 125 km (Figure 5). From west to east, these are termed the Bayhead, Cape Strawberry, October Harbour, Dog Islands and Tukialik granites. All of these plutons have very similar characteristics, and they are considered to be equivalent, and of closely similar age. Each pluton is dominated by coarse grained, homogeneous, white, pink or red, K-feldspar porphyritic to megacrystic, biotite granite, commonly containing accessory fluorite. The granites from the type area (Cape Strawberry, near Makkovik) are described in most detail below. Some important features of the Strawberry Intrusive Suite are illustrated in Plates 10 and 11.

Cape Strawberry Granite and Related Rocks

Definition and Extent. Granitoid rocks exposed in the Cape Strawberry–Wild Bight area form the type locality for the Strawberry Intrusive Suite. The Cape Strawberry and October Harbour granites correspond to part of Unit 29 of Gower *et al.* (1982), and the Poodle Pond granite was formerly included in their Unit 28a (Monkey Hill Granite). The Cape Strawberry granite is dominated by coarse-grained, pink or red porphyritic biotite granite, associated with subordinate fine-grained material; the October Harbour granite tends to be white in colour, but is similar in compositional terms. The Poodle Pond granite consists of at least two sill-like bodies of medium grained equigranular granite emplaced within Upper Aillik Group metavolcanic rocks. Single and multiphase aplite, granite and pegmatite dykes and sheets cut the Upper Aillik Group throughout the area around Cape Strawberry. Many are fluorite-bearing, and they are considered to be minor intrusions related to the Strawberry Intrusive Suite. Some pegmatites near Ford's Bight (55°08'N, 59°07'W) host molybdenite mineralization (Gower *et al.*, 1982; Wilton and Wardle, 1987).

Description of Rock Types. The granites of the Cape Strawberry area vary considerably in texture and composition. The most abundant rock type is a massive, unfoliated, pink to orange-red, coarse-grained, variably K-feldspar porphyritic, biotite granite to alkali-feldspar granite, commonly containing conspicuous purple fluorite. In thin section, typical examples consist of quartz (20 to 45 percent), microcline (40 to 70 percent), plagioclase (An_{15-25}; 10 to 35 percent), biotite and chlorite (1 to 6 percent; biotite replaced by chlorite), hornblende (rare; normally replaced extensively by biotite). Prominent accessory phases include fluorite, as interstitial material and associated with mafic mineral aggregates, allanite (locally as euhedral crystals up to 3 mm in length), zircon, sphene and iron oxides.

Igneous textures are well-preserved. Quartz forms anhedral masses, but locally displays an interstitial habit. Microcline is commonly a coarse patch-perthite, with variable hematite alteration. Free plagioclase is invariably present, suggesting a subsolvus environment of crystallization, but is commonly confined to the groundmass. Red-brown biotite almost invariably displays alteration to yellowish chlorite, concentrated along cleavage traces, and multiple biotite–chlorite 'sandwiches' are very characteristic. In rocks that have extensive hematization, chlorite is commonly the only mafic phase.

Fine-grained, locally miarolitic, equigranular variants occur locally around contacts, crosscut contacts, and form

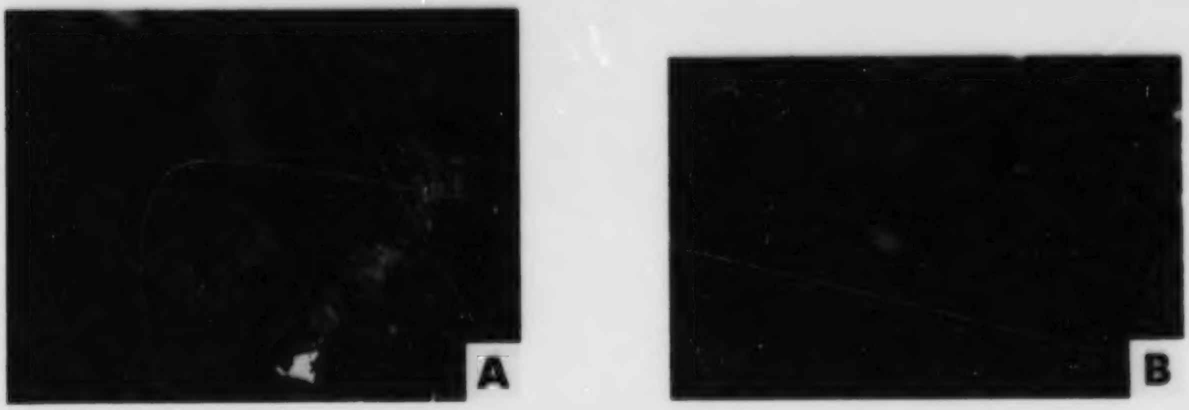


Plate 9. *Features of the Numok Intrusive Suite (plagiophyric monzonite unit). a) Monzonite with zoned, ovoidal, plagioclase phenocrysts and interstitial pyroxene-amphibole. b) Plagioclase-rich variant (cumulate ?), with oikocrystic mafic minerals. Both samples from area west of Big River. Slabs are stained for K-feldspar.*

most of the Poodle Pond granite. A distinctive fine to medium grained grey phase is present in the northeast part of the Cape Strawberry granite, and occurs as xenoliths in the coarse facies, suggesting that it is an early component. Locally, this shows a diffuse foliation and ghostly inclusion textures suggesting that it could be an altered Upper Aillik Group porphyry, but in other areas it is massive and resembles a fine-grained version of the granite. The Cape Strawberry granite also contains distinctive mafic mineral accumulations with a trough-bedded, locally crossbedded, geometry indicative of cumulate processes. It also contains a single large (10 by 10 m) block of rhythmically layered granitoid. The presence of such features suggests a low viscosity during crystallization of the granite, which is probably due to its high fluorine content.

Fine-grained phases of the Cape Strawberry granite mostly have a similar mineralogy to the dominant coarse-grained phase, but are commonly miarolitic and/or graphic in texture. The distinctive grey phase in the northeast of the body contains poikilitic crystals of deep-blue reibeckite or arfvedsonite amphibole, and displays some evidence of recrystallization in quartz and feldspars. If it is an early phase, this may be a thermal effect from the main coarse-grained granite. 'Cumulate' mafic mineral layers consist of euhedral biotite and hornblende crystals, associated with euhedral sphene, allanite and zircon. They indicate at least local fractionation of biotite and accessory minerals by physical accumulation due to gravity settling.

Field Relationships. The contact zones of the Cape Strawberry granite range from clean, sharp boundaries to zones of interaction and hybridization where the Upper Aillik Group country rocks appear strongly altered. The northeastern contact of the pluton is steep where exposed on the coast, but the southern contact is more complex, and several enclaves of country rock occur adjacent to it, within the granite. These are interpreted as small roof pendants, and this contact probably dips gently southward.

Xenolith-rich zones near contacts contain fragments of fine-grained granite, Aillik Group metavolcanic rocks, and various 'hybrid' rock types. Brecciated zones with a biotite-rich matrix are present in xenoliths and in outcrops close to contacts. Alteration, bleaching and pyritization of adjacent country rocks are locally evident adjacent to contacts. Irregular silicified zones, aplites and pegmatites crosscut the contacts. These features suggest volatile exsolution and hydrothermal activity, which in turn suggest a relatively high level of emplacement. Amphibolites in country rocks at the margin of the October Harbour granite contain calcite–diopside–andradite ± fluorite skarn-like patches, and the margin of the granite itself contains a pale green-brown (andradite?) garnet that is probably a xenocrystic phase derived from this material.

Geochronology. Two samples from the Cape Strawberry granite have been dated by U–Pb zircon methods (Kerr and Krogh, 1990; Kerr *et al.*, 1992). Initial results from a typical coarse-grained granite were discordant due to Pb loss, but indicated a general age of 1800 to 1760 Ma, significantly older than the previously assumed 1650 Ma age. A second sample was collected from a 'cumulate' mafic mineral layer that contained euhedral, low-uranium zircons. U–Pb data from these were almost concordant at 1719 ± 3 Ma. The Cape Strawberry granite (and, by inference, other members of the Strawberry Intrusive Suite) is thus some 70 to 80 Ma younger than most of the other dated posttectonic Makkovikian granitoid rocks. However, in view of the strong geochemical affinities between these associations, it has been included with the posttectonic Makkovikian group.

Wanless *et al.* (1970) report K–Ar (biotite) ages of 1565 ± 50 and 1600 ± 34 from the Cape Strawberry granite. A composite Rb–Sr isochron from four plutons of the suite (Kerr, 1989a) yields an age of 1694 ± 56 Ma, but shows evidence of disturbance (i.e., an unreasonably low initial Sr isotope ratio). Nevertheless, it is within error of the 1719 ± 3 Ma U–Pb age.

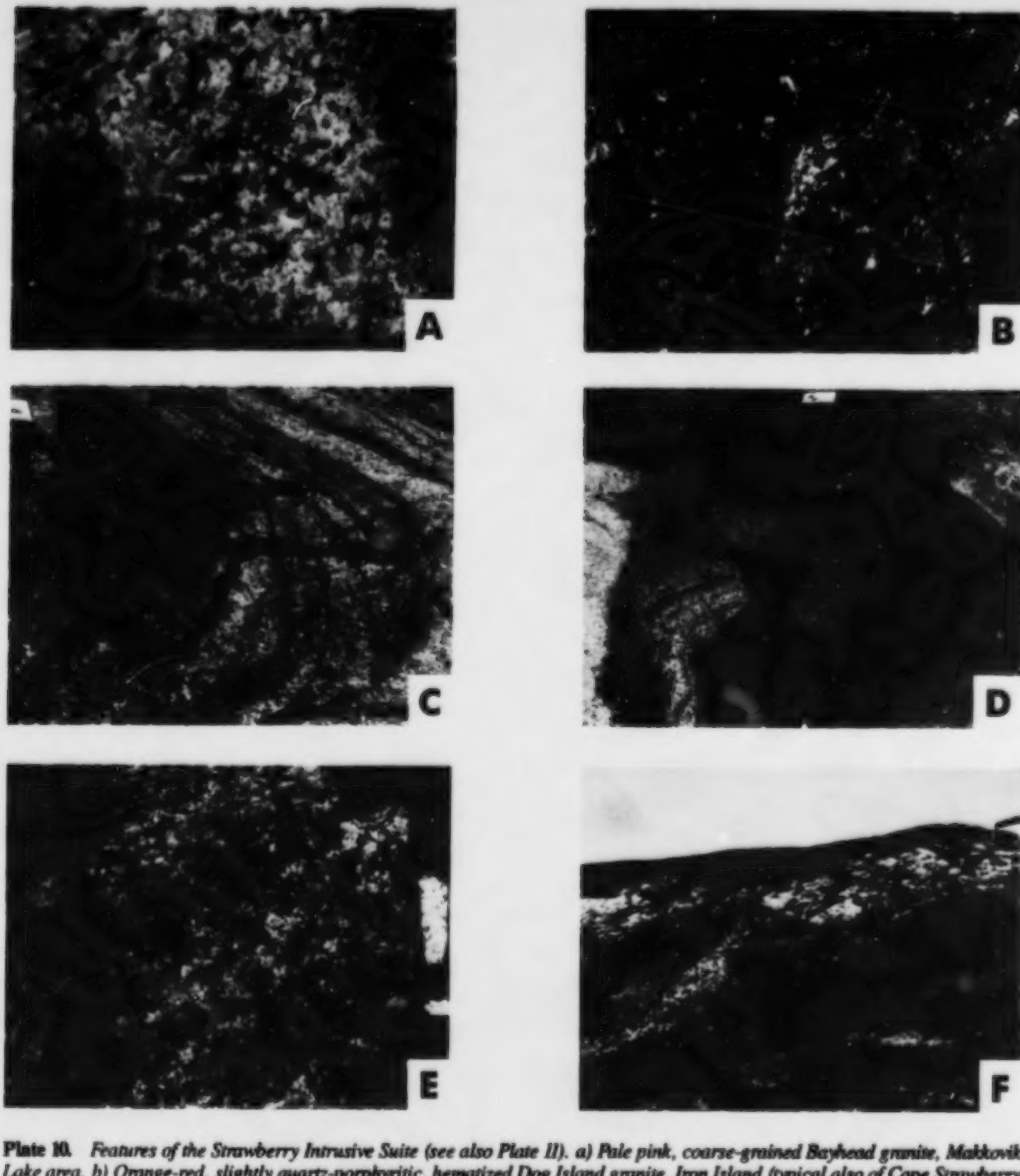


Plate 10. *Features of the Strawberry Intrusive Suite (see also Plate 11). a) Pale pink, coarse-grained Bayhead granite, Makkovik Lake area. b) Orange-red, slightly quartz-porphyritic, hematized Dog Island granite, Iron Island (typical also of Cape Strawberry granite). c) Trough-bedded, cumulate, mafic mineral layering, near Cape Strawberry. d) Rhythmically layered granite block, Ford's Bight. e) "Tuffisite" breccia, near southern contact of Cape Strawberry granite. f) Sill of fine-grained, white-weathering granite, with feeder dyke, near Poodle Pond. Sill has a thickness of between 30 and 50 m, and intrudes the Upper Aillik Group (grey in photo).*

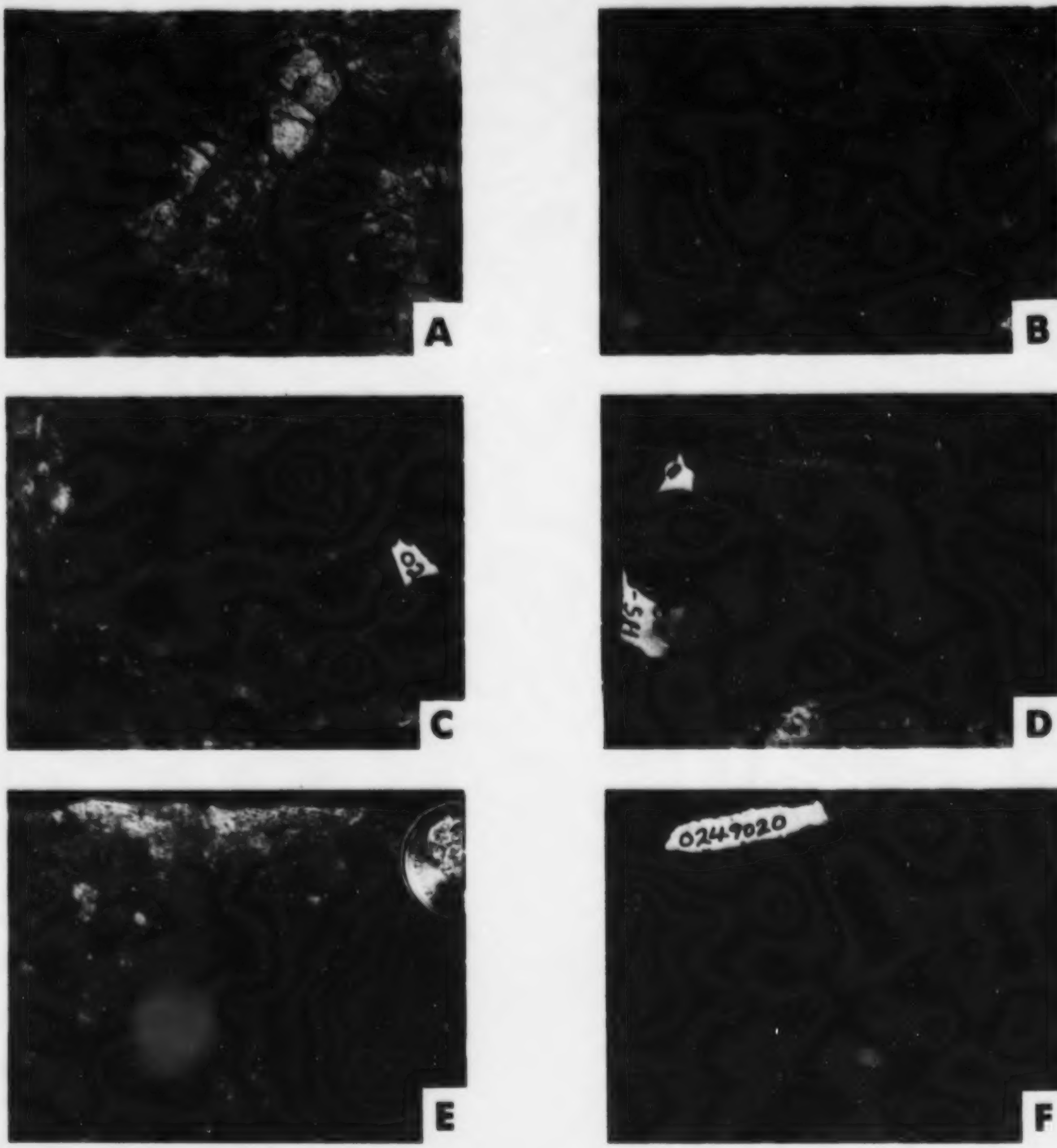


Plate 11. *Features of the Strawberry Intrusive Suite (see also Plate 10). a) Molybdenite-bearing pegmatite, Ford's Bight. b) Melanocratic variant of the Bayhead granite, south of Kaipokok Bay. c) Typical Cape Strawberry granite. d) Fine-grained, reibeckite-bearing, grey phase of Cape Strawberry granite. e) Quartz-feldspar porphyry associated with Dog Islands granite, note oscillatory feldspar zoning. f) Medium-grained, variably porphyritic Tukialik granite. Slabs stained for K-feldspar.*

Bayhead Granite

This is a new subdivision of the regionally extensive Unit 27 of Gower *et al.* (1982). Its southern boundary is formed by the Adlavik Brook fault zone, and its northern boundary by an inferred fault that truncates part of the Upper Aillik Group and an inlier of presumed Archean gneiss. Contact relationships of the unit are thus unknown. No displaced equivalent of the Bayhead granite has been recognized south of the Adlavik Brook fault zone, suggesting that it was either restricted to the north side or perhaps that the (presumably upthrown) block to the south represents a level of the crust below its emplacement level. K–Ar data from this unit (Wanless *et al.*, 1970) gave an age of 1570 ± 50 Ma. On the basis of correlation with the Cape Strawberry granite, it is considered here to be ca. 1720 Ma old.

The Bayhead granite is closely similar in geology and petrology to the type area of the Strawberry Intrusive Suite, but is dominated by homogeneous coarse-grained granite and only minor fine-grained material. In compositional terms, it is the least differentiated pluton in the Strawberry Intrusive Suite. It is relatively melanocratic (up to 10 percent total mafic minerals), locally plagioclase- porphyritic, and commonly contains minor relict amphibole. Most of the unit is homogeneous, although it includes a few gabbroic blocks up to 10 m in diameter. Faint mafic mineral layering is present locally, and probably has a 'cumulate' origin akin to that of the more striking layering observed in the Cape Strawberry granite.

Dog Islands Granite

The name Dog Islands granite is introduced for granites exposed on Dog Island, Iron Island, Burnt Island, and the adjacent mainland (Figure 5), corresponding to Units 17 and 18 of Gower (1981). Fluorite-bearing quartz-feldspar porphyry dykes that resemble this granite cut quartz monzonite of the Numok Intrusive Suite on nearby islands. This suggests a maximum age of ca. 1800 Ma; correlation with the Cape Strawberry granite suggests an age of ca. 1720 Ma. The Dog Islands granite is almost identical in petrological terms to the granite in the type area of the Strawberry Intrusive Suite, but is more homogeneous, and locally quartz-porphyritic. Mafic mineral layering occurs at the western end of Iron Island (see also Gower, 1981), and is interpreted here as a cumulus feature. A syenite to quartz syenite variant present in the east of Dog Island and on Burnt Island (corresponding partly to Unit 18 of Gower, 1981) locally contains distinctive blue poikilitic amphibole (reibeckite or arfvedsonite). A pleochroic, green, clinopyroxene (probably aegirine-augite) is present in one sample. Other mafic phases include green hornblende and biotite, associated with fluorite, zoned allanite and euhedral zircon. The mineralogy of this syenitic variant is very similar to the fine-grained, marginal, grey phase of the Cape Strawberry granite.

Feldspar and quartz-feldspar porphyry dykes assigned to the Dog Islands granite are mineralogically similar to the coarse phase. Quartz phenocrysts show rounded and resorbed outlines. K-feldspar phenocrysts locally contain cores of saussuritized plagioclase and, in one instance, alternating rings of K-feldspar and plagioclase indicate oscillatory growth. Chloritized biotite, fluorite, magnetite and sphene form interstitial clots.

Tukialik Granite

Tukialik granite is a new name introduced for rocks exposed on Bear Island and in the eastern Benedict Mountains, corresponding to Unit 23 of Gower (1981). It consists dominantly of coarse grained, pink, biotite granite and alkali-feldspar granite similar to other members of the Strawberry Intrusive Suite.

The unit is in contact with monzonite and syenite of the Mount Benedict Intrusive Suite along its southern boundary; this contact is interpreted to be the continuation of the transcurrent Adlavik Brook fault zone in the west. The nature of the southern contact in the east is unknown. To the west, the Tukialik granite may be physically continuous with the Dog Islands granite. D.G. Bailey (field notes, 1979) suggests that the granite was gradational with an enclave of metavolcanic rocks east of Tukialik Bay; however, this enclave is locally cut by veins of pink granite.

In comparison to other members of the Strawberry Intrusive Suite, the Tukialik granite is richer in K-feldspar, slightly finer grained, and locally equigranular. Blue quartz is prominent in many samples. A quartz-feldspar porphyry variant occurs locally on Bear Island and resembles similar rock types grouped with the Dog Islands granite. Alteration of biotite to chlorite appears less intense than in the Cape Strawberry or Dog Islands granites.

Lanceground Intrusive Suite

Definition and Distribution

Lanceground Intrusive Suite is a new, formal name introduced for three discrete plutons; two of these (Lanceground Hills and Pistol Lake granites) are located near Adlavik Bay, whereas the third (Tarun granite) is located in an inland area, adjacent to the Adlavik Brook fault zone (Figure 5). The name is derived from the local name for the site of Anders and Bridget Andersen's fishing cabin, located within the granite of the same name. All three units show closely similar characteristics, but the Tarun granite has been affected by Grenvillian deformation and metamorphism. There appears to be a spatial association between these granites and the ca. 1800 Ma old Numok Intrusive Suite, although a case could also be made for a spatial link to the ca, 1650 Ma Adlavik Intrusive Suite. A Rb–Sr isochron from the Lanceground Hills granite (Kerr, 1989a; Kerr and Krogh, 1990) suggests an ambiguous age of 1692 ± 32 Ma, but the systematics are probably disturbed, as they give a very low initial Sr isotope ratio. The Lanceground Intrusive Suite shows a strong geochemical affinity to other known members of the posttectonic Makkovikian association, and contrasts with known Labradorian (ca. 1650 Ma) granitoid rocks. The suite may belong to either the dominant ca. 1800 Ma association,

or to the subordinate 1720 Ma association represented by the Strawberry Intrusive Suite.

Lanceground Hills and Pistol Lake Granites

Definition and Extent. The Lanceground Hills granite corresponds to part of Unit 26c of Gower *et al.* (1982), and the Pistol Lake granite to part of their Unit 28a (Monkey Hill Granite). The two units are, however, closely similar, and neither has any resemblance to the Monkey Hill Granite; in this area, the units of Gower *et al.* (1982) were mostly based on the work of BRINCO geologists.

Description. Both units consist dominantly of pink to buff or brown, coarse grained, K-feldspar porphyritic, biotite–hornblende syenite, quartz syenite, granite and alkali-feldspar granite. Some features of these units are illustrated in Plate 12. Many examples contain only a single coarsely perthitic K-feldspar, and appear to have crystallized under hypersolvus conditions. Free plagioclase, where present, is largely confined to the groundmass, although one sample contained rounded plagioclase phenocrysts, mantled by K-feldspar. Both units are generally fresh and massive, although the western part of the Lanceground Hills granite locally displays a moderate northeast to east-trending foliation. Syenitic variants resemble equivalent rocks assigned to the Numok Intrusive Suite, and parts of the Lanceground Hills granite show the same intense weathering to yellow gravel.

In thin section, typical examples consist of quartz (5 to 35 percent), microcline (50 to 80 percent), plagioclase (An_{10-25}; up to 25 percent, excluding perthite lamellae), biotite and hornblende (up to 10 percent, proportions variable), clinopyroxene (up to 2 percent, commonly relict, possibly aegirine-augite). Blue, sodic amphibole, and fayalitic olivine occur rarely, and accessory zircon, allanite, fluorite and sphene are prominent in most samples. Round clots of iron-oxide and amorphous brown material are interpreted as pseudomorphs after original fayalite. Biotite is commonly a red-coloured, iron-rich, variety, and normally predominates over green-blue amphibole.

Igneous textures are mostly well preserved. Quartz and mafic minerals commonly display an interstitial habit; the latter are locally poikilitic. Microcline phenocrysts are composed of coarse, string-type perthite (clearly visible in stained slabs), and have relict simple twinning suggesting a primary orthoclase or sanidine. Hornblende locally contains ragged cores of greenish clinopyroxene. Fluorite is interstitial, or associated with mafic clots, and prominent euhedral zircon crystals, locally up to 4 mm in length, are notable.

Field Relations and Age. Contact zones of the Lanceground Hills granite coincide with the agmatite zone at the western margin of the Numok Intrusive Suite. A dyke of brown-weathering, hypersolvus, quartz syenite (typical of the suite) cuts the foliated agmatite, indicating that emplacement of the granite post-dated the leucosome (dated at ca. 1800 Ma) and also its deformation (unconstrained). The relationship between the Lanceground Hills granite and adjacent gabbro–diorite of the Adlavik Intrusive Suite is unknown. The Pistol Lake granite is in contact with the Upper Aillik Group for 10 km, but most of the contact is obscured by drift. The granite intrudes the Aillik Group in two localities, and is locally intruded by biotite-bearing gabbro that resembles parts of the Adlavik Intrusive Suite.

Tarun Granite

The Tarun granite is located near the Benedict fault zone, both north and south of White Bear Mountain. It corresponds to part of Unit 26c ('Tarun syenite') of Gower *et al.* (1982). More northerly parts of their Unit 26c are here grouped with syenite of the Numok Intrusive Suite. Original igneous textures and mineralogy of the Tarun granite have been obliterated by recrystallization in many samples. Well-preserved examples are pink or buff, coarse grained, K-feldspar porphyritic granites that resemble the granites of the type area for the Lanceground Intrusive Suite; there is also a strong geochemical similarity between them.

Contact relationships of the Tarun granite are poorly known. The northern limit is difficult to place as there is relatively little contrast between the granite and syenite–quartz syenite of the Numok Intrusive Suite. The most likely position coincides with the projected trace of a fault indicated by Gower *et al.* (1982); alternatively, the two might actually be gradational. The similarity in texture and mineralogy to fayalite-bearing syenites of the Numok Intrusive Suite argues in favour of this possibility, but there is as yet no proof.

The Tarun granite is also spatially associated with quartz-feldspar porphyry (assigned to the Upper Aillik Group) that forms the main peak of White Bear Mountain. The northern contact of the porphyry unit (from Gower *et al.*, 1982) is approximately coincident with the 1200 to 1400 ft (400 to 475 m) contour interval, and follows the topography. It is suggested that this contact has a shallow inclination, and that the Tarun granite is continuous beneath the peak. The nature of the granite–porphyry contact is unknown, but there is a strong compositional similarity between them that may indicate a genetic link.

Big River Granite

Definition and Extent

This is a new, formal name proposed for an extensive granitoid unit in the southeast of the study area (Figure 5). It corresponds to Unit 26b and part of Unit 23 of Gower et al. (1982). The name is derived from Big River, which lies at the northwestern edge of the body.

Description

The Big River Granite is dominated by pink to red or white, coarse grained, K-feldspar porphyritic, leucocratic, hornblende–biotite granite and alkali-feldspar granite, locally ranging in composition to quartz monzonite and quartz syenite. Some of these features and units are illustrated in Plate 13. Textural variants include the dominant porphyritic

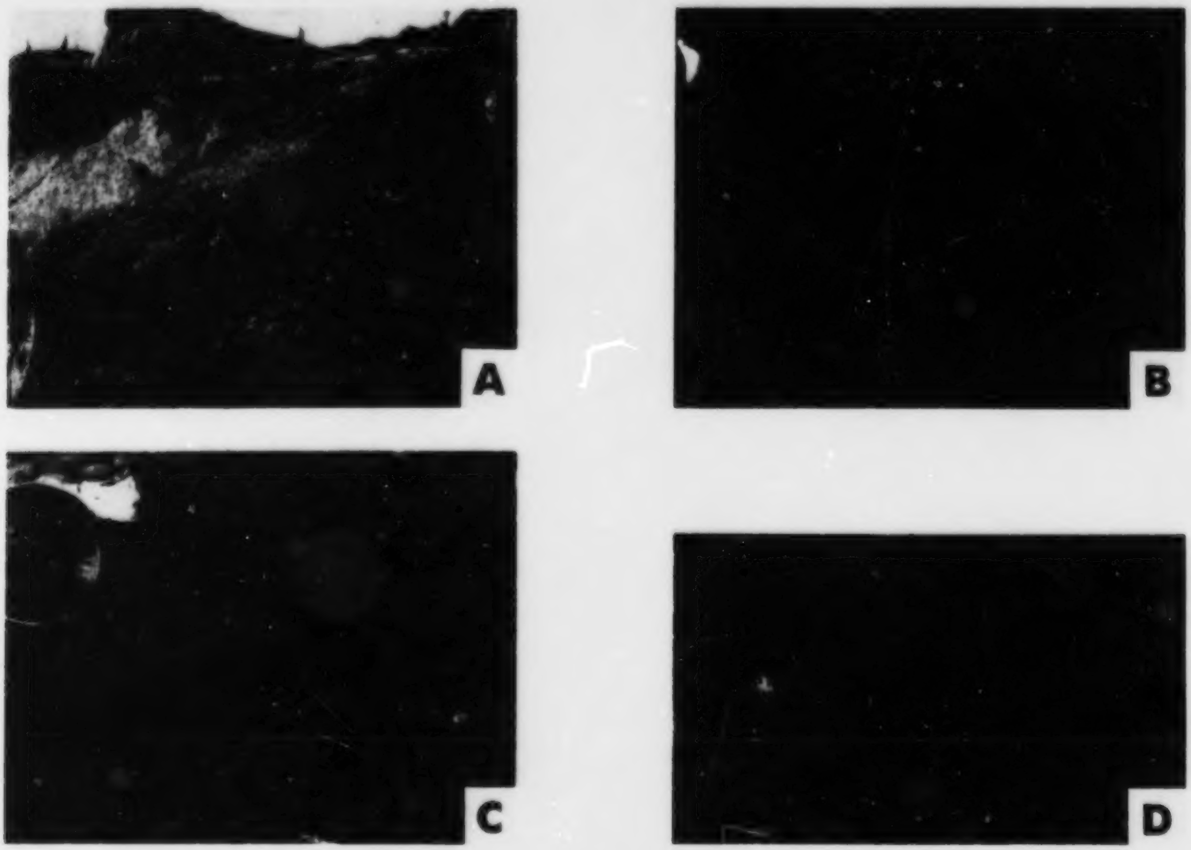


Plate 12. *Features of the Lanceground Intrusive Suite. a) Intense weathering of the Lanceground Hills granite, near Adlavik Bay, probably indicating the former presence of fayalite. b) Hypersolvus syenite, Adlavik Bay. Note coarse perthite, and similarity to Numok Intrusive Suite syenites (Plate 8). c) Alkali-feldspar quartz syenite of the Pistol Lake granite, south of Bernard Lake. d) Coarse-grained, deformed alkali-feldspar granite from the Tarun granite, near White Bear Mountain. Slabs stained for K-feldspar.*

granitoid, and a subordinate medium- to coarse-grained, equigranular phase. The former is characterized by mantled plagioclase phenocrysts with K-feldspar rims for which the term 'pseudorapakivi texture' is used here (classical rapakivi or 'wiborgite' textures consist of albite on orthoclase, e.g., Vorma, 1976). This pseudorapakivi texture is variably developed, but is present in at least vestigial form in most porphyritic variants. The unit is generally massive and undeformed in the northern part of its outcrop area, but develops a sporadic cataclastic fabric in the south. Foliations have a general east–west trend, but are locally variable. The transition from foliated to massive granite appears to be gradational, and the cataclastic rocks probably form local zones of high strain parallel to the Benedict fault zone. Close to the Benedict fault zone, it locally has an 'augen-gneiss' texture.

In thin section, typical examples consist of quartz (20 to 35 percent), microcline (40 to 70 percent), plagioclase (An_{20-35}; 10 to 40 percent), hornblende and biotite (2 to 10 percent in total; hornblende dominant), clinopyroxene (up to 2 percent, mostly relict) and minor iron oxide, sphene, allanite, epidote, zircon and fluorite. Disseminated pyrite occurs in one locality. The pseudorapakivi variants are characterized by composite, rounded phenocrysts consisting of zoned, saussuritized plagioclase cores enveloped by microcline–perthite rims. In most cases, there is a single mantle only; oscillating zones of plagioclase and K-feldspar are very rare.

Igneous textures are well-preserved in the northern part of the unit, where interstitial quartz crystals are clear in thin section. Both K-feldspar and plagioclase occur in the groundmass; mafic minerals form prominent clots, associated with accessory mineral concentrations. In the southern part of the unit, mafic minerals are partially replaced by epidote, sphene and chlorite.

Hornblende in the Big River Granite is a deep-green or blue-green variety. Pale green, locally faintly pleochroic

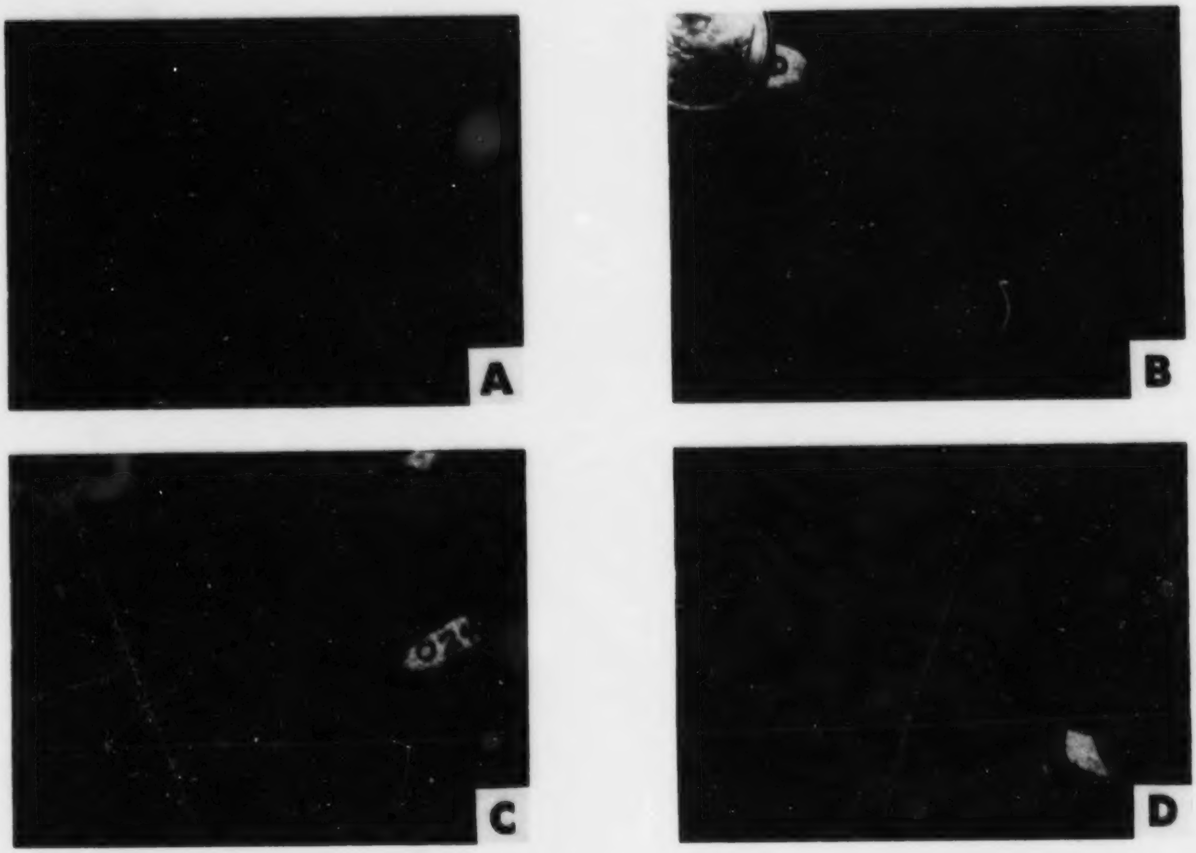


Plate 13. *Features of the Big River Granite. a) Red-weathering pseudorapakivi granite, south of the estuary of Big River. Note ovoidal phenocrysts. b) Fine-grained, porphyritic phase, in which the feldspar zoning is partly defined by mafic inclusion trails, near Big River. c) and d) Typical coarse-grained pseudorapakivi granites from the escarpment east of Big River Valley. Slabs stained for K-feldspar.*

clinopyroxene (possibly aegirine–augite) is present rarely as a relict phase, altered to amphibole and/or biotite. Gower (1981) also reports reibeckite in two such samples from the unit, but this mineral does not appear to be widespread in the unit. Sphene is a prominent minor phase (up to 1 percent in some samples), and is commonly euhedral. Other accessory phases are prominent, but not as abundant as in the Strawberry and Lanceground Intrusive suites. Medium-grained equigranular variants occur mostly in the southeast and northwest of the unit. They are more siliceous than the dominant porphyritic phase and have a higher biotite to hornblende ratio.

Field Relations and Age

The western boundary of the unit coincides with an inferred northeast-trending fault zone that links the Benedict and Adlavik Brook fault zones, and is marked by a prominent linear escarpment. The southern boundary corresponds with the Benedict fault zone. The nature of the poorly-exposed eastern boundary is unclear; a foliated grey dioritic granitoid sporadically observed in this area is atypical of most of the unit, and may represent a screen of older material between it and adjacent units to the east.

A Rb–Sr isochron from the dominant porphyritic granite (Kerr, 1989a) yields an age of 1798 ± 28 Ma, and shows no evidence of disturbance. U–Pb zircon dating was subsequently conducted on a coarse-grained porphyritic granite, and gave a concordant age of 1802 ± 2 Ma (Kerr and Krogh, 1990; Kerr *et al.*, 1992).

Freshsteak and Noarse Lake Granitoids

Definition and Extent

The Freshsteak and Noarse Lake granitoids are located in two separate inland areas north of White Bear Mountain and northwest of Maclean Lake respectively (Figure 5). These two areas are underlain by closely similar rock types, and

are interpreted to be portions of an originally continous pluton, that has been displaced dextrally by the Adlavik Brook fault zone (Figure 5). The northern area (Freshsteak granitoid) is a new subdivision of the regionally extensive Unit 27 (undivided granitoid rocks) of Gower *et al.* (1982). The southern area (Noarse Lake granitoid) is broadly equivalent to Unit 13 of Bailey (1979), and was grouped also by Gower *et al.* (1982) in their Unit 27. The names are derived from names given to lakes by BRINCO geologists in these areas.

Description

The Freshsteak and Noarse Lake granitoids are both dominated by brown to grey, medium-grained, plagioclase porphyritic, melanocratic quartz monzonite, granodiorite and monzogranite. Both units are relatively melanocratic, and typically contain small, equant, plagioclase phenocrysts up to 1 cm in diameter. Slight foliations, of variable orientation, are present close to the trace of the Adlavik Brook fault zone; the Noarse Lake unit shows generally more intense recrystallization than the Freshsteak granitoid.

In thin section, typical examples consist of quartz (10 to 30 percent, generally less than 20 percent), microcline (30 to 50 percent), plagioclase (An_{25-40}; 30 to 50 percent), hornblende and biotite (5 to 20 percent in total, normally greater than 10 percent, subequal amounts), clinopyroxene (relict), and accessory sphene, apatite, zircon and allanite. Plagioclase phenocrysts commonly have zoned and/or saussuritized cores, and locally have clear, albitic rims. Groundmass quartz and feldspar are variably recrystallized, but graphic quartz/K-feldspar intergrowths or angular interstitial quartz grains are preserved in many areas. Where unrecrystallized, hornblende is locally poikilitic.

The field and petrographic characteristics of these units are similar to massive and weakly deformed examples of the Long Island Quartz Monzonite.

Field Relations and Age

Contact relationships of both units are unknown. The Freshsteak granitoid is well-exposed (except along its southern margin), but the Noarse Lake granitoid is poorly exposed. The full areal extent of this unit is uncertain, as a large area to its east is totally obscured by glacial drift. Matching of plutonic units and the Upper Aillik Group after removal of dextral displacement along the Adlavik Brook fault zone suggests that the Noarse Lake granitoid may underly much of this unexposed area, but this cannot be proved. If so, the larger area occupied by this unit presumably indicates changes in the dimensions of the original magma chamber with depth. A Rb–Sr isochron from the Freshsteak granitoid indicates an age of 1798 ± 48 Ma (Kerr, 1989a), suggesting that this is a Makkovikian intrusion of probable posttectonic affinity. The Rb–Sr age obtained for the Freshsteak unit is similar to K–Ar and U–Pb ages from the Long Island Quartz Monzonite (Gandhi *et al.*, 1969, 1988), which is, as noted, similar in many respects.

Stag Bay Granodiorite

Definition and Extent

This unit is located around Stag Bay, in the eastern part of the Benedict Mountains. It corresponds to Unit 19 of Gower (1981), and to a portion of the regionally extensive Unit 26 of Gower *et al.* (1982). Gower (1981) grouped the unit with megacrystic granodiorite exposed near Deus Cape (Deus Cape granodiorite, see Syntectonic Makkovikian plutonic rocks), and with similar megacrystic granitoids east of the study area in the vicinity of Byron Bay.

Description

The unit includes a variety of rock types, the most abundant of which is a grey to pink or buff, coarse-grained, seriate to two-feldspar porphyritic granodiorite, monzogranite or granite (see also description of Gower, 1981). K-feldspar and plagioclase are commonly both present as phenocryst phases; the former are generally larger, ranging up to 5 cm in size. In the north, the unit is generally massive, but the southern part is locally foliated and/or cataclastic in texture. This area is cut by several faults that link the Adlavik Brook and Benedict fault zones, and foliation directions are highly variable. Gower (1981) indicates north-trending foliations in two areas near the coast that were not visited during this study.

In thin section, typical examples (if such exist) consist of quartz (15 to 35 percent), microcline (25 to 65 percent), plagioclase (15 to 50 percent), hornblende (up to 5 percent), green biotite (5 to 10 percent) and accessory sphene, apatite, zircon and allanite. Chlorite and epidote are abundant in foliated and altered variants. Quartz is variably strained, but locally retains an interstitial habit. Plagioclase phenocrysts are commonly zoned and variably saussuritized, particularly in their cores. The amount of recrystallization is highly variable.

Field Relations and Age

Contact relationships of the unit are unknown. At Stag Bay, the coarse-grained granitoids are cut by a feldspar-porphyry dyke which may be related to the nearby Dog Islands granite, but might also be associated with nearby subvolcanic porphyry units assigned to the Upper Aillik Group. Rb–Sr data yielded a 5 point 1714 ± 44 Ma isochron (Kerr, 1989a). U–Pb zircon dating (Kerr and Krogh, 1990) is incomplete. However, a single zircon fraction plots close to concordia, suggesting an age in the range of 1805 to 1790 Ma (Kerr *et al.*, 1992). There is therefore little doubt that this unit belongs to the Makkovikian group of intrusions, and is probably of ca. 1800 Ma age.

LABRADORIAN PLUTONIC ROCKS

This association comprises post-Makkovikian, largely undeformed, posttectonic plutonic rocks for which

geochronological data and/or field relationships suggest ages between 1670 and 1600 Ma. As discussed previously, the term 'posttectonic' does not imply a universal absence of deformation, as some units in the south have east-trending foliations of probable Grenvillian age. There is no clear evidence of Labradorian deformation in the study area, as posttectonic Makkovikian plutonic suites are undeformed, except in the south. The term 'anorogenic', however, is not appropriate for Labradorian plutons, as there is clear evidence for Labradorian deformation and metamorphism in high-grade terranes to the south at about 1650 Ma (e.g., Wardle *et al.*, 1986). Thus, Labradorian plutonism may be temporally related to these events, but the study area apparently lay outside the zone affected directly by metamorphism and deformation.

Labradorian plutonic rocks are here divided into five main associations (Figure 6). The Adlavik Intrusive Suite consists of layered gabbro, leucogabbro and diorite. The Mount Benedict Intrusive Suite includes minor diorite and gabbro of similar aspect, but is dominated by monzonite to quartz syenite. Both of these suites appear to have been derived by fractionation of mafic parental magmas. The Monkey Hill Intrusive Suite comprises a number of small, leucocratic, epizonal granite plutons that intrude the Upper Aillik Group around Makkovik Bay. The Witchdoctor granite and Burnt Lake granite are similar leucocratic granites exposed in the southwest of the area. The Otter Lake–Walker Lake granite is a regionally extensive porphyritic quartz monzonite to granite unit exposed in the extreme west of the area. The latter two associations lie close to the trace of the Benedict fault zone, and have been variably affected by Grenvillian deformation.

Adlavik Intrusive Suite

The Adlavik Intrusive Suite includes layered gabbroic and dioritic rocks exposed at Adlavik Bay and Big River valley, and also as a number of isolated bodies, of which the most important is at Pamiulik Point, in the Benedict Mountains (Figure 6). The type locality at Adlavik Bay is referred to below as the 'main body'.

The main body was defined initially by Gandhi *et al.* (1969) and Stevenson (1970), and termed 'Adlavik Complex'; this was later modified to Adlavik Intrusive Suite by Gower (1981). A U–Pb zircon date of 1649 $\pm$ 1 Ma was obtained from a potassic monzodiorite at Adlavik Bay (Kerr and Krogh, 1990; Kerr *et al.*, 1992). Gower *et al.* (1982) summarize previous K–Ar dates (mostly by Gandhi *et al.*, 1969; Wanless *et al.*, 1970) from minor intrusions possibly related to the suite; these range from 1660 to 1540 Ma. A postulated link to the Numok Intrusive Suite (Kerr, 1986) has since been disproved by the ca. 1800 Ma U–Pb zircon ages from the latter (Kerr and Krogh, 1990; Kerr *et al.*, 1992).

The main body of the Adlavik Intrusive Suite is a complex, layered, multi-component intrusion. The scale of mapping and sampling in this regional project is incapable of resolving all of the problems inherent in its geometry and stratigraphy, and the following account is undoubtedly an oversimplification.

Mafic Plutonic Rocks

Definition, Extent and Subdivision.

These correspond to Unit 13 of Gower (1981) and subunit 22a of Gower *et al.* (1982), and exhibit great variety in composition and texture. Various features of these rocks are illustrated in Plates 14 and 15. Their distribution corresponds in general terms to that outlined by Gower *et al.* (1982). Clark (1973) mapped the northern fringe of the main body (as part of a Ph.D. thesis topic), and outlined five subunits or 'facies'. These have been revised and augmented during this project (Kerr, 1989a; Figure 7), and are used as a framework for description. The following description apply mostly to the main body; other areas of the suite are dominated by melagabbro and leucogabbro facies described below. It must be stressed that lithological variations occur within the Adlavik Intrusive Suite on scales well below that of Figure 7, or the scale of field mapping. Units denoted on the figure should therefore be regarded only as guides to the most abundant variant or 'facies' within a particular area. Most of the intrusion is dominated by (relatively) homogeneous leucogabbro and melagabbro facies. The marginal gabbro and diabase is restricted to the contact zones, and probably represents a chilled margin. The mafic cumulate facies, which includes some ultramafic rocks, is best developed in areas interpreted to represent the base or sidewall of the intrusion, but also forms local zones in the melagabbro and leucogabbro. The gabbroic pegmatite and composite diabase facies are crosscutting on an intrusion-wide scale, and also cut the diorite unit. They are not discriminated as separate units on the map.

Marginal Gabbro and Diabase. This is best exposed in the Big Bight area, but also occurs locally around the western edge of the main body, where it forms a thin (usually < 5 m) discontinous margin against the Upper Aillik Group country rocks. It is a fine- to medium-grained, equigranular grey rock having a variably diabasic texture. In the Big Bight area, it contains primary acicular hornblende and is closer to diorite in composition. In parts of the mafic cumulate facies, it occurs as rounded xenoliths or pillows in coarse gabbro. These agmatites probably record disruption of a chilled margin by slightly later magma, also suggested by Gower (1981) for a similar texture at Pamiulik Point.

Mafic Cumulate Facies. This corresponds partly to the rhythmic layered facies of Clark (1973). It is well-exposed at Big Bight, where it forms the base or side of the intrusion. It is also present locally within the dominant leucogabbro facies and the diorite unit. Rhythmic layering, graded bedding, and crossbedding are well developed in these rocks. At Big Bight, they form at least two irregular cyclic units of the type shown schematically in Figure 8. Each cycle commences with coarse-grained ultramafic rocks, dominated by amphibole and biotite, but with a relict pyroxenite mineralogy. These are interlayered with and overlain by layered gabbro and

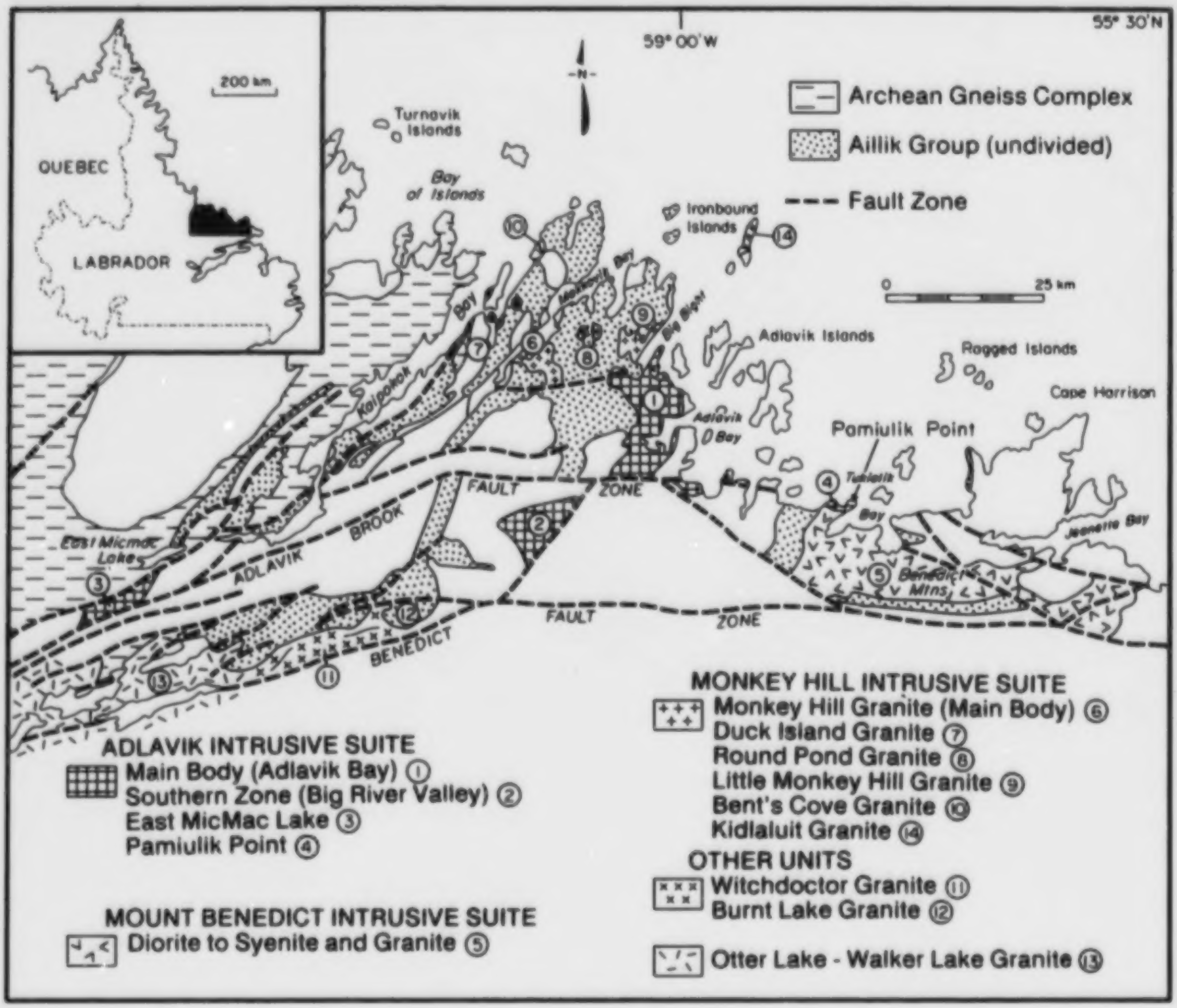


Figure 6. *Summary map illustrating the distribution and extent of Labradorian plutonic units.*

gabbronorite, where hornblende crystals with a 'stubby' habit (after pyroxene ?), containing augitic cores, define rhythmic layering and graded bedding. The upper portion of each cycle consists of very coarse-grained amphibole-bearing 'gabbroic pegmatites' (gabbroic pegmatite facies; see below for discussion) that also occur as irregular, diffuse, veins and pods that disrupt the underlying cumulates.

Melagabbro Facies. The mafic cumulate facies is overlain in the Big Bight area by massive, dark grey to black, coarse-grained, melanocratic rocks (termed 'massive diabase facies' by Clark, 1973, but not generally diabasic), which in turn grade upward into the dominant leucogabbro facies. The melagabbro generally contains less than 50 percent plagioclase; it is locally a gabbronorite, but in most areas mafic phases have been transformed to amphibole. It is locally strongly epidotized around networks of fractures or veinlets.

Leucogabbro Facies. This areally dominant facies is a grey to white or purple-brown, coarse to very coarse grained, leucogabbro or leucogabbronorite. It is distinguished from the melagabbro by a higher plagioclase content (up to 70 percent), but the two are gradational. It contains interstitial (locally oikocrystic) mafic minerals and locally has a magmatic foliation defined by plagioclase alignment. Diffuse mafic mineral accumulations and thin zones of rhythmic layering provide evidence of cumulus processes, and it is viewed as a plagioclase cumulate. Leucogabbronorite is restricted to the northern margin and inner part of Adlavik Bay, but many samples retain only relict primary mineralogy and it is therefore difficult to assess the original extent of orthopyroxene and olivine-bearing rocks.

This facies is homogeneous, except for locally voluminous crosscutting composite diabase and gabbroic

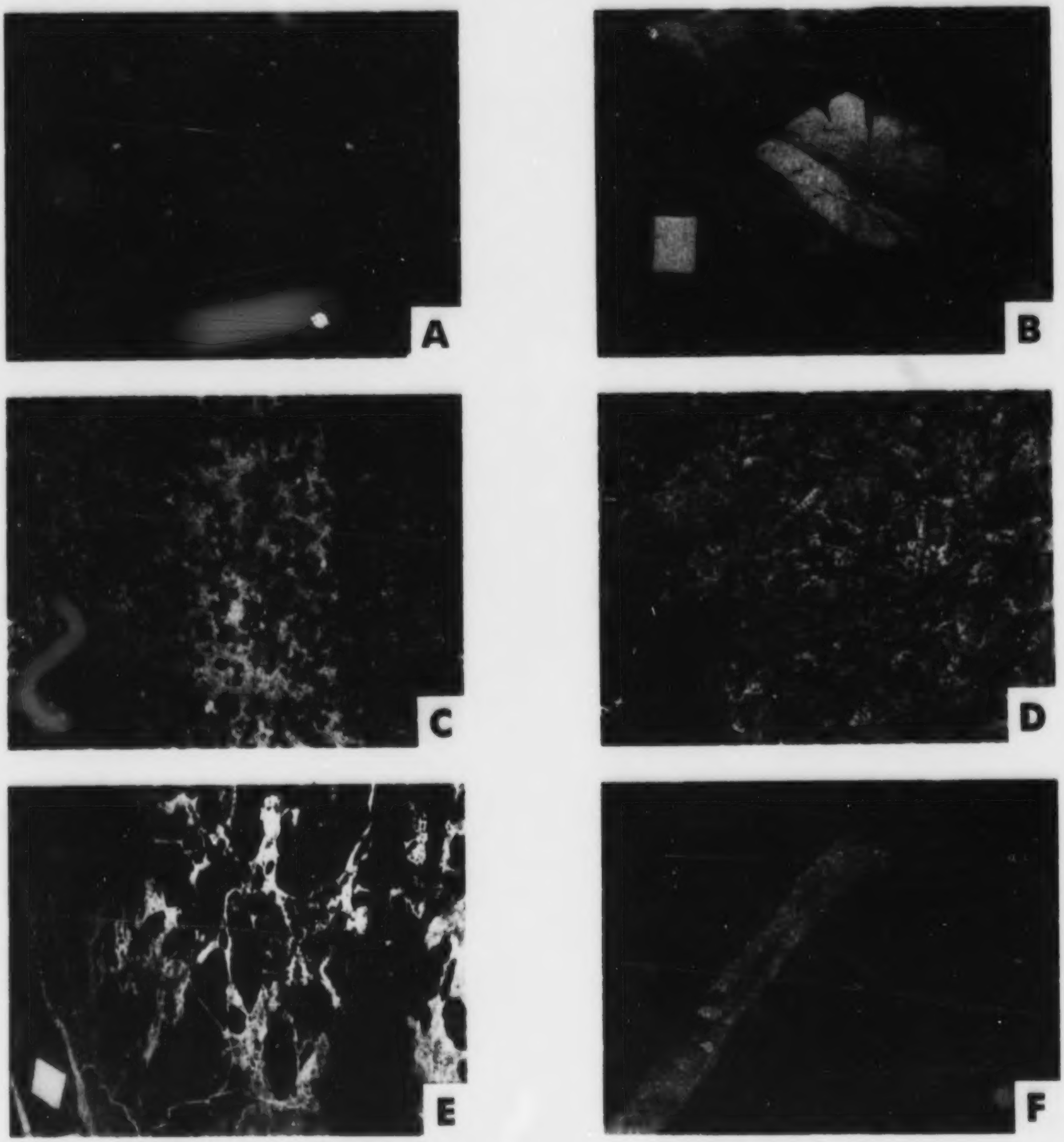


Plate 14. Features of mafic rocks in the Adlavik Intrusive Suite (see also Plate 15). a) Mafic cumulate with amphibole megacrysts up to 5 cm diameter, containing augite cores, Pamiulik Point area. b) Stoped blocks of diorite in melanocratic gabbro, Adlavik Bay. c) Graded bedding in mafic cumulate, Big Bight, tops to right of photo. d) Coarse 'diabasic' texture, probably a plagioclase cumulate, coastline south of Manak Bay. e) Composite diabase body intruding leucogabbro facies, Adlavik Bay. Note chilled margins on diabase lozenges. f) Detail of 14e from same locality, white vein is about 5 cm wide. Note disruption of chilled margins by grey, intermediate material.

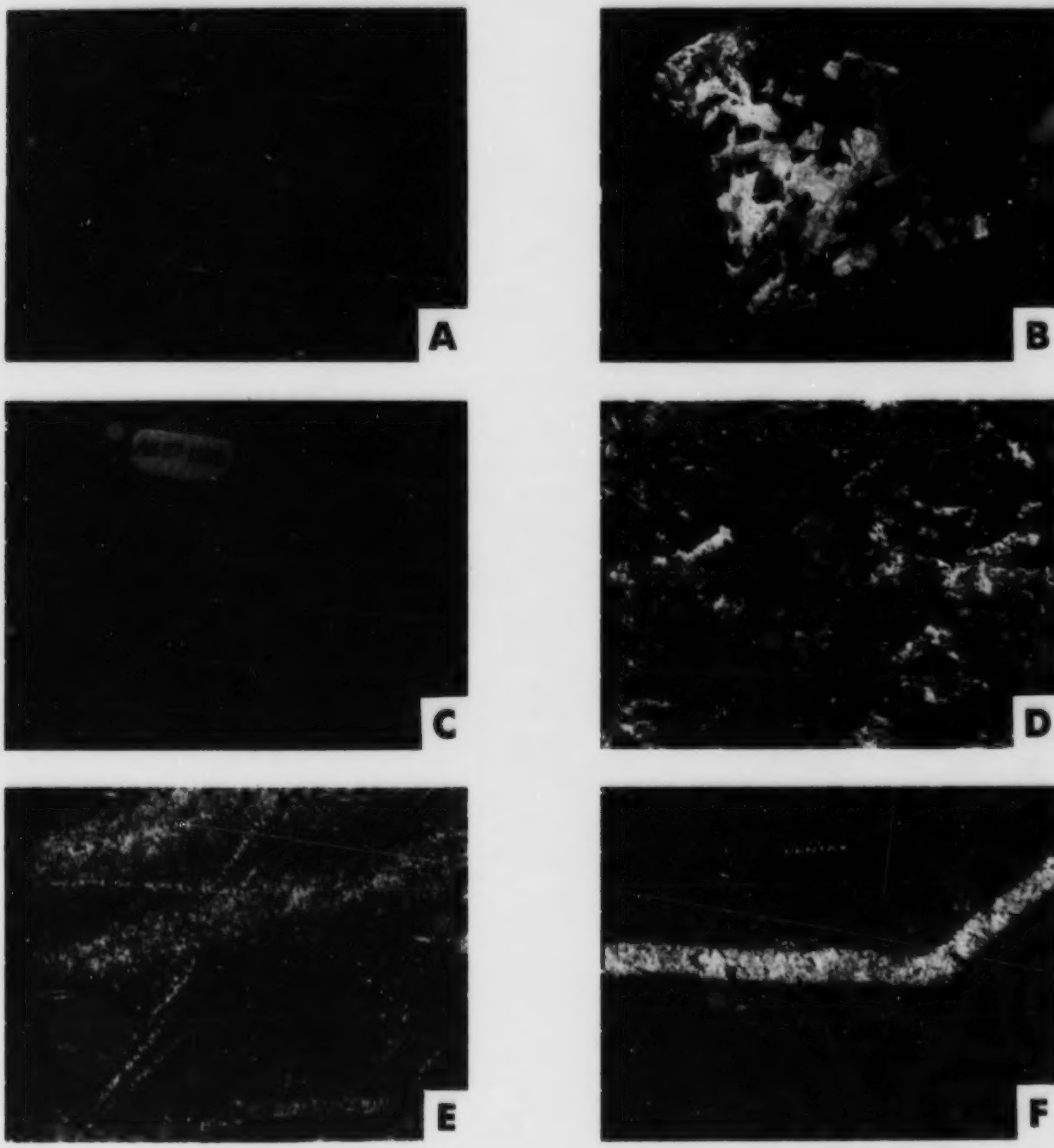


Plate 15. *Features of mafic rocks in the Adlavik Intrusive Suite (see also Plate 14). a) and b) Typical plagioclase-cumulate leucogabbro samples. c) Amphibole phenocrysts (after pyroxene) in a fine-grained variant from Big Bight; note cores (altered augite). d) Amphibole-bearing pegmatite, with unusual, hollow hornblende crystals up to 2 cm in diameter (cross-section), Adlavik Bay. e) Pervasive zones of epidotization in melagabbro facies, Big Bight. f) Amphibolitization of gabbro around thin felsic veinlet, Jacques Island. Slabs stained for K-feldspar.*

pegmatite. In one locality, it includes angular, stoped blocks that resemble the diorite unit.

Gabbroic Pegmatite Facies. This consists of coarse-grained, generally quartz-free, gabbroic and dioritic 'pegmatite', containing acicular hornblende (locally forming unusual hollow crystals), and variable amounts of K-feldspar. It is associated with the mafic cumulate facies and occurs as

sporadic masses (rarely more than 400 m^2) that intrude all the above and the diorite unit. In the mafic cumulate facies, it is probably a local volatile-rich residual magma formed by crystallization of the underlying cumulates. It is suggested that it forms a late phase formed by the operation of similar processes on an intrusion-wide scale.

Composite Diabase Facies. Fine- to medium-grained diabase forms numerous outcrop-scale dykes, veins and irregular masses that intrude and disrupt both the mafic rocks and the diorite unit. These commonly have a chaotic internal structure, where diabase is intruded and disrupted by grey, intermediate material that appears to originate in the local wall rocks. Chilled margins are present around individual diabase 'pillows', but these are cut and net-veined by this intermediate material. Preferred orientation of diabase lozenges in some areas suggests that these were zones of flow, and they are interpreted as conduits through which mafic magma batches ascended to higher parts of the intrusion. They were probably emplaced into hot, partly consolidated cumulates that contained residual liquid capable of mobilization and interaction with ascending mafic magma. Their presence in the diorite unit indicates that multiple batches of mafic magma were emplaced at Adlavik Bay, and that diorite is not the youngest component.

Petrographic Features

As might be expected from the great variability of these rocks, it is difficult to give a concise petrographic description. Typical examples of the dominant melagabbro and leucogabbro facies consist of plagioclase (An_{40-80}; 30 to 75 percent), clinopyroxene (augite, 10 to 50 percent), orthopyroxene (geographically restricted; 5 to 20 percent where present), hornblende ± actinolite (5 to 50 percent, commonly after pyroxene), biotite (red, 5 to 20 percent), olivine (minor, but 5 to 20 percent in gabbronorites), quartz and K-feldspar (up to 7 percent, interstitial), and minor iron oxide, sphene and apatite.

These rocks range from fresh variants where plagioclase, pyroxene and biotite are the dominant minerals to altered variants dominated by hornblende, saussuritized plagioclase and actinolite. Most samples lie between these extremes, and commonly contain hornblende as mantles on pyroxene crystals, suggesting that it is a late primary phase or a post-magmatic alteration product. In strongly hydrated variants, clinopyroxene (± orthopyroxene) occurs only locally as relict cores in hornblende/actinolite masses. Red biotite is present in hornblende-free rocks, and is therefore probably part of the primary assemblage.

This mineralogical continuum is interpreted to reflect variations in the water content of the magma during crystallization (cf. Clark, 1973). Although some pyroxene-free rocks (especially gabbroic pegmatites and parts of the diorite unit) contain euhedral, primary hornblende, it is suggested that most were modified extensively by late-magmatic or deuteric effects. In some areas, amphibolitization is concentrated around fractures or thin felsic veinlets, indicating that at least some of this transformation was post-crystallization.

Fresh gabbronorite variants contain variable amounts of pleochroic hypersthene, and fresh to locally relict olivine, commonly mantled by orthopyroxene aggregates. Olivine does not occur widely in orthopyroxene-free rocks, but many are olivine-normative. Ultramafic rocks, and associated mafic cumulates, contain large (up to 10 cm) megacrysts or crystal aggregates of amphibole with cores of clinopyroxene. They contain abundant pale (Mg-rich?) biotite (possibly phlogopite), and were probably originally biotite-pyroxenites. Examples of the composite diabase facies are similar, but finer grained.

Field Relations and Age

The mafic rocks of the Adlavik Intrusive Suite intrude the Upper Aillik Group around its margins. In the Big Bight area, they are intruded by leucogranite dykes and veins that are assigned to the Monkey Hill Intrusive Suite, dated at its type locality at ca. 1640 Ma (Kerr *et al.*, 1992). No K–Ar or Rb–Sr data have been obtained from the main body of the Adlavik Intrusive Suite.

Diorite and Monzodiorite

Definition and Extent

The most extensive area of this unit is in the main body (Figure 7), but similar rocks occur at Pamiulik Point and East Micmac Lake. It is more homogeneous than the mafic component of the Adlavik Intrusive Suite, but locally resembles the more leucocratic members of the leucoggabbro facies.

Description

The dominant rock type is a pale brown- to pink- or yellow-weathering, coarse-grained, equigranular to plagioclase porphyritic, pyroxene–hornblende–biotite or two-pyroxene diorite, quartz diorite or monzodiorite. Some features of this unit are illustrated in Plate 16.

Discontinous mafic mineral layers, primary foliations defined by plagioclase alignment, and thin (< 10 m) zones of mafic cumulates occur locally. The unit is cut by the composite diabase facies, and zones of coarse amphibole-feldspar pegmatite; the latter also occurs as isolated patches within coarse diorite that probably represent local volatile-rich pockets.

In thin section, typical examples consist of plagioclase (An_{40-50}; 40 to 65 percent), quartz (up to 8 percent, intergrown with K-feldspar), K-feldspar (5 to 25 percent; as interstitial granophyre), clinopyroxene, hornblende and biotite (10 to 20 percent in total), orthopyroxene (up to 10 percent), and accessory apatite, iron oxide and zircon.

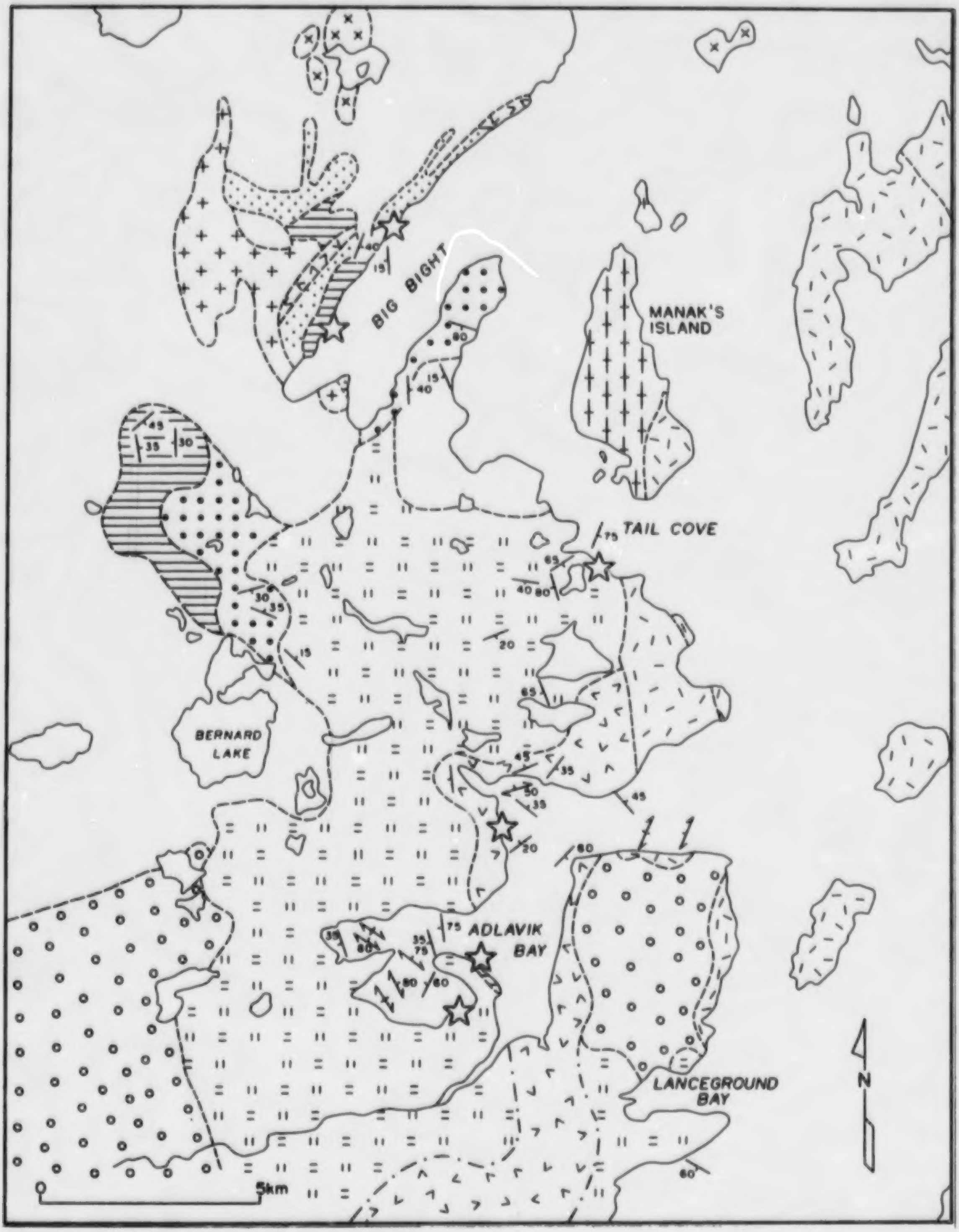


Figure 7. *Simplified geological map of the main body of the Adlavik Intrusive Suite (partly after Clark, 1973, Gower* et al., *1982 and Kerr, 1988a).*

LEGEND (Figure 7)

LABRADORIAN PLUTONIC ROCKS

MONKEY HILL INTRUSIVE SUITE

Little Monkey Hill Granite

ADLAVIK INTRUSIVE SUITE

Diorite and Monzodiorite

Leucogabbro Facies

Melagabbro Facies

Mafic Cumulate Facies

Marginal Gabbro and Diorite

POSTTECTONIC MAKKOVIKIAN PLUTONIC ROCKS

NUMOK INTRUSIVE SUITE

Monzonite to Quartz Syenite

STRAWBERRY INTRUSIVE SUITE

Poodle Pond Granite and October Harbour Granite

LANCEGROUND INTRUSIVE SUITE

Lanceground Hills and Pistol Lake Granites

SYNTECTONIC MAKKOVIKIAN PLUTONIC ROCKS

Manak Island Granodiorite

SUPRACRUSTAL ROCKS

Upper Aillik Group (undivided)

SYMBOLS

Geological contact (approximate, inferred)

Igneous layering or foliation

Penetrative foliation

Fault (inferred)

Location of pegmatitic gabbro–diorite material containing minor sulphide

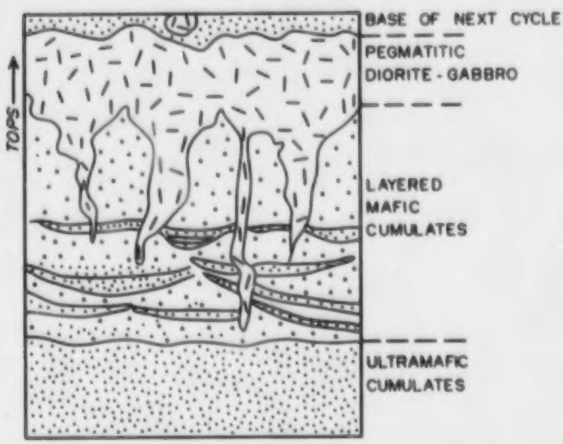


Figure 8. *Schematic illustration of cyclic units in the Mafic cumulate facies in the Big Bight area, at the northern margin of the main body of the Adlavik Intrusive Suite.*

As in the mafic rocks of the suite, there is a continuum from near-anhydrous variants to rocks which lack pyroxene entirely and are dominated by amphibole. However, some of the latter contain euhedral, probably magmatic hornblende. Red-brown biotite is present in most examples, and its presence appears independent of amphibole content, suggesting that it is always of primary origin. K-feldspar and quartz are interstitial and late. A few plagioclase-rich diorites contain both hypersthene and augite, suggesting a possible link to the gabbronoritic variants of the mafic sequence.

Field Relations and Age

At Adlavik Bay, the diorite appears to be gradational with the adjacent plagioclase cumulates. But, it also includes angular xenoliths of homogeneous gabbro and mafic cumulate indicating that it is younger than at least some of the mafic rocks. However, gabbro exposed on the shoreline of the southwestern inner bay of Adlavik Bay includes stoped blocks of a rock type that resembles the diorite. It appears, therefore, that there are at least two generations of mafic rocks within the suite, and possibly more. A potassic diorite collected near the mouth of Adlavik Bay yielded a concordant U–Pb zircon age of 1649 ± 1 Ma (Kerr and Krogh, 1990; Kerr *et al.*, 1992).

Geometry and Stratigraphy of the Adlavik Bay Layered Intrusion

There are wide variations in primary layering attitudes within single outcrops around Adlavik Bay. Reconstruction of the geometry and stratigraphy of the intrusion is thus very difficult. It is not certain that layering represents the same reference orientation in all locations, or that all components were originally conformable; in fact, field relationships suggest that there are probably a number of internal intrusive contacts.

Layering attitudes around Adlavik Bay indicate, however, that the diorite unit is at least partly overlain by mafic rocks (assuming that their mutual contact is parallel to layering in both). A possible interpretation (Figure 9) is that the diorite is associated with a lower, gabbronoritic sequence that is overlain (perhaps 'unconformably') by gabbro and

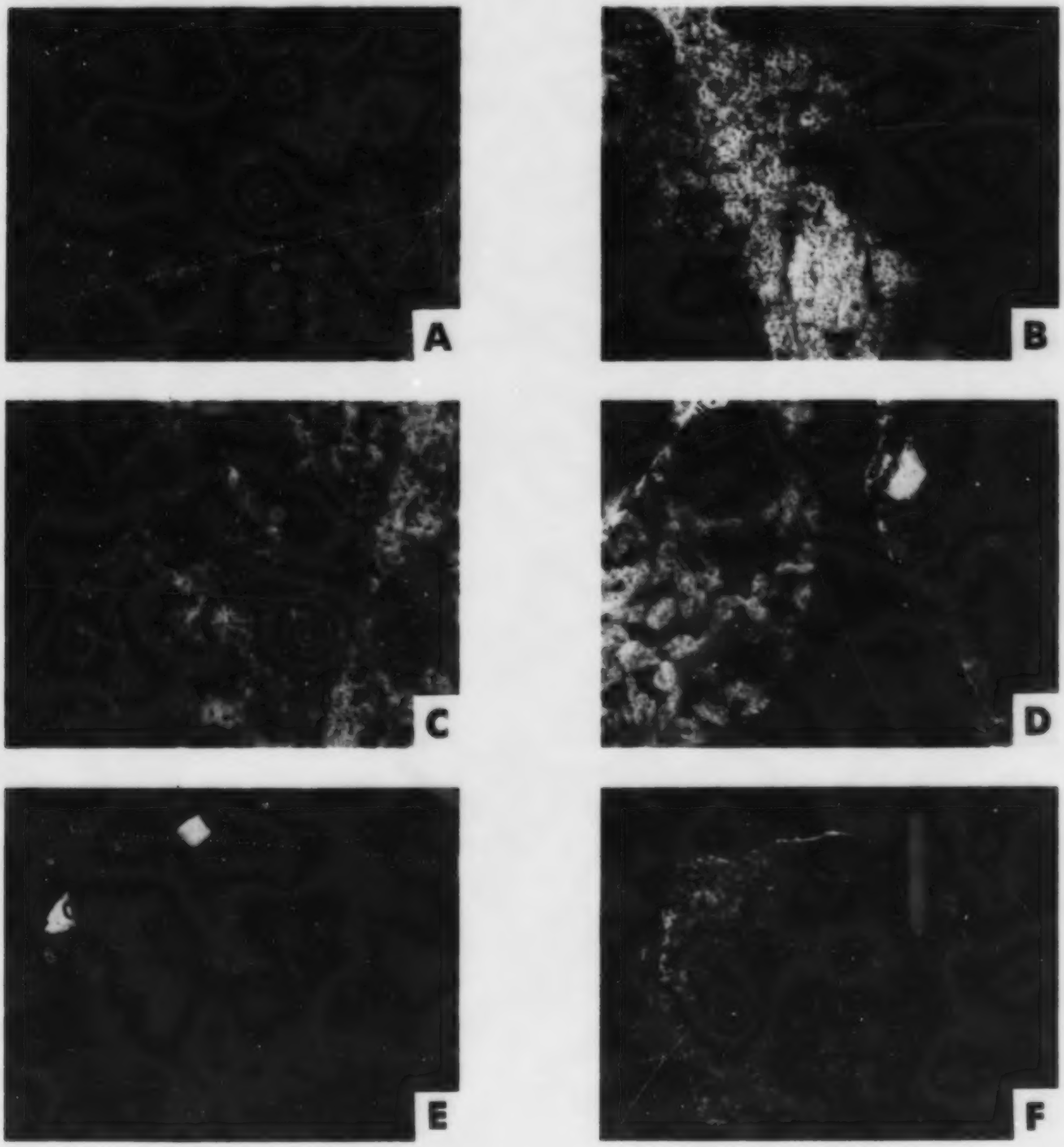


Plate 16. *Features of the dioritic unit in the Adlavik Intrusive Suite. a) Typical homogeneous diorite, with wispy mafic mineral layers suggesting cumulus processes, Adlavik Bay. b) Xenoliths of leucogabbro and cumulate-layered gabbro (layered xenolith about 20 cm diameter) in diorite, Adlavik Bay. c) Coarse-grained, plagioclase-rich variant, probably a plagioclase cumulate, Adlavik Bay. d) Typical examples of diorite unit, Adlavik Bay, note interstitial K-feldspar. e) Monzonitic to syenitic variant of unit. f) Fine-grained, marginal, diorite with acicular hornblende, Big Bight area. Slabs stained for K-feldspar.*

leucogabbro. Contrasts in normative mineralogy also indicate that there are spatially discrete gabbronorite and gabbro sequences (see section on Descriptive Geochemistry). It must be stressed this is only one of a number of possible interpretations. The schematic cross-section in Figure 9 is intended to convey the possible complexity of this intrusion! The composite diabase facies is interpreted as the feeder system for higher parts of the intrusion, and the pegmatite

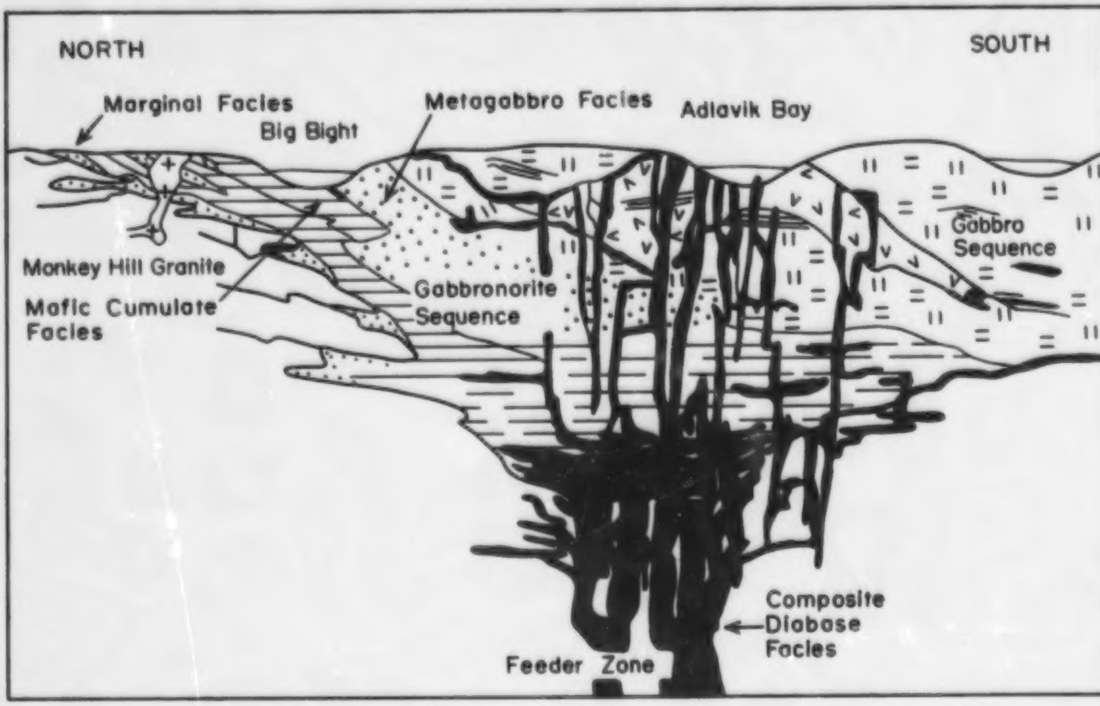


Figure 9. *Schematic, interpretative cross-section of the main body of the Adlavik Intrusive Suite.*

facies as residuum from the crystallization of individual batches of magma.

Mount Benedict Intrusive Suite

Definition and Distribution

Mount Benedict Intrusive Suite is a new, formal name introduced for a series of compositionally varied rocks exposed in the Benedict Mountains (Figure 6; 54°45'N, 58°45'W). The term is not synonymous with 'Benedict Mountains Intrusive Suite', initially introduced by Gower (1981) as a general label for intrusive rocks throughout this area. It is recommended that this older term now be abandoned, as it includes both Makkovikian and Labradorian plutonic rocks, which cannot be directly related as part of a 'suite'. The three units of the Mount Benedict Intrusive Suite correspond generally to textural variants described by Gower (1981) of his Unit 21. They form a continuum from diorite and monzodiorite through monzonite and syenite to granite (*ss*). Some features of the suite are illustrated in Plate 17. The overlap between them suggests that they are closely related and probably mutually gradational. The boundaries of units within the suite are very generalized, as significant small-scale lithological variations occur within single outcrops.

Gabbro and Diorite

Definition and Extent. Gabbro and diorite are restricted mostly to the southwestern edge of the Mount Benedict Intrusive Suite, but also occur sporadically within the other two units. An area of mafic cumulates, melagabbro and monzodiorite exposed at Pamiulik Point (grouped here as part of the Adlavik Intrusive Suite) may also belong to this unit. Gower (1981, personal communication, 1988) states that there is no obvious structural break between these rocks and the syenite to the south. As discussed subsequently, the similarity between the least evolved rocks of the Mount Benedict Intrusive Suite and parts of the Adlavik Intrusive Suite, and their geochemical continuity (see Descriptive Geochemistry section) suggests a genetic link between them.

Description. This unit consists of plagioclase-porphyritic pyroxene (± olivine)-bearing gabbro, leucogabbro and diorite, locally transitional to monzonite. Plagioclase alignment, and the oikocrystic habits of mafic minerals, indicate a cumulate origin.

In thin section, typical examples consist of quartz (up to 2 percent, interstitial habit), microcline (5 to 20 percent, interstitial, with quartz), plagioclase (An_{40-60}; 50 to 80 percent, saussuritized) clinopyroxene ± orthopyroxene (5 to 20 percent total), olivine (up to 10 percent, mostly relict), and accessory apatite and iron oxide. Several samples contain equant serpentine–iron oxide clots with cores of fresh olivine. Fresh examples contain pleochroic hypersthene, and a purple to brown titanaugite with prominent exsolution lamellae (probably an inverted pigeonite). Red-brown biotite is also common. Altered variants consist of saussuritized plagioclase, hornblende and actinolite (± epidote, sphene). This unit has

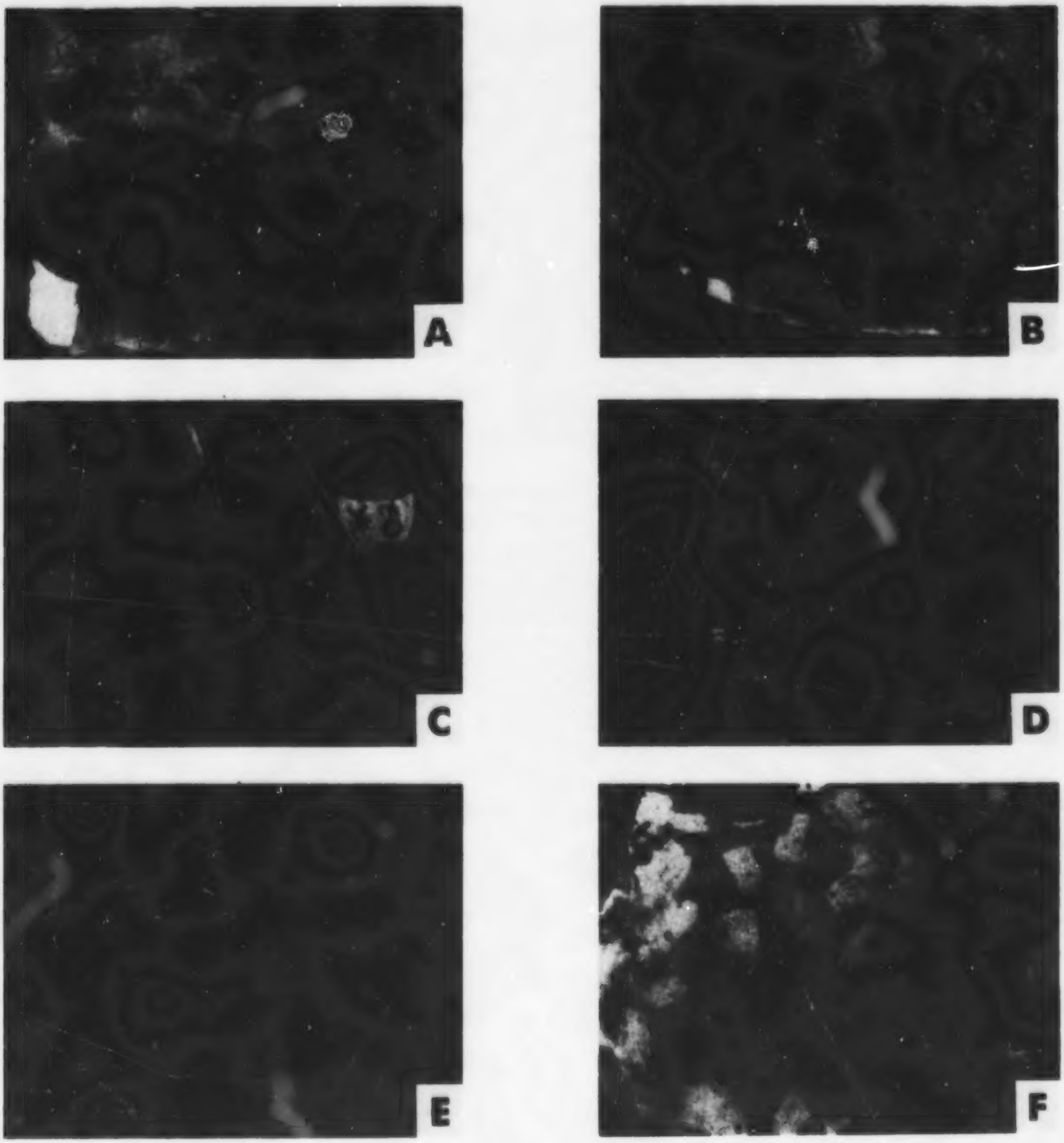


Plate 17. *Features of the Mount Benedict Intrusive Suite. A continuum of compositions from plagioclase cumulate a), through diorite b), monzonite–syenomonzonite c), syenite d) and to quartz syenite e). (Note persistence of vestigial plagioclase phenocrysts in all but e). f) A combination of textures, with plagioclase crystals entrained in syenite. All samples from the Mount Benedict–Jeanette Bay area. Slabs stained for K-feldspar.*

obvious petrographic similarities to gabbro and diorite of the Adlavik Intrusive Suite.

Monzonite, Syenomonzonite and Syenite

Definition and Extent. This unit is the most abundant component of the Mount Benedict Intrusive Suite. It forms a compositional and textural continuum from plagioclase-porphyritic, pyroxene monzodiorite to coarse-grained, biotite–hornblende syenite containing only minor plagioclase.

Description. The dominant rock type is a grey to buff, seriate to porphyritic, biotite–hornblende monzonite, quartz monzonite or syenomonzonite (i.e., potassic monzonite). It is commonly plagioclase-porphyritic, although the contrast in grain size between groundmass and phenocrysts is slight. The groundmass consists of a medium-grained aggregate of quartz, K-feldspar and mafic silicates. Gower (1981) termed this 'speckled-eggshell texture', and suggested that the plagioclase phenocrysts had been resorbed by the magma. In some samples, plagioclase phenocrysts have K-feldspar rims, and resemble pseudorapakivi feldspars such as those in the Big River Granite. Speckled-eggshell texture is present throughout the unit, but is developed most widely in monzonite and syenomonzonite; syenitic rocks contain only scattered vestigial plagioclase phenocrysts.

In thin section, typical examples consist of quartz (up to 10 percent, interstitial habit), plagioclase (two generations, 30 to 60 percent), microcline (20 to 40 percent), hornblende and biotite (5 to 15 percent in total), clinopyroxene (up to 5 percent, relict), and accessory sphene, zircon, allanite and fluorite. Plagioclase phenocrysts are zoned and saussuritized, whereas the groundmass material forms clear laths. Zoned phenocrysts commonly have clear rims of more sodic composition. Igneous textures are very well preserved through most of the unit. interstitial quartz, or graphic quartz–K-feldspar micropegmatite, occurs widely. Mafic minerals form aggregates of subhedral to euhedral crystals. Relict clinopyroxene occurs in the cores of euhedral hornblende crystals in mafic variants. Locally, hornblende crystals have sphene cores, suggesting early crystallization of the latter.

Syenite, Quartz Syenite and Granite

Definition and Extent. This unit is prevalent on the higher peaks of the Benedict Mountains, and is best exposed around Mount Benedict itself. It also occurs sporadically within the dominant monzonite–syenite. Its partial restriction to higher elevations suggests that it may be a roof facies (Gower, 1981) or, alternatively, the uppermost portion of a compositionally layered body. The latter interpretation is supported by systematic geochemical changes with elevation (see section on Descriptive Geochemistry).

Description. This unit is dominated by homogeneous, pink, grey or buff coloured, locally porphyritic, fine- to medium-grained, leucocratic, syenite, quartz syenite or granite. Potash feldspar is a common phenocryst phase, but vestigial plagioclase phenocrysts and speckled-eggshell texture are present locally. In one location, it contains large (2 cm), embayed plagioclase crystals that appear to have been entrained in syenitic magma. The unit locally grades into a feldspar or quartz-feldspar porphyry of subvolcanic aspect, suggesting a high level of emplacement. Rapid local variations in grain size occur in many outcrops.

In thin section, typical examples consist of quartz (5 to 15 percent, locally up to 30 percent), K-feldspar (50 to 80 percent), plagioclase (sodic; 10 to 35 percent), biotite and hornblende (up to 5 percent, biotite dominant), and accessory sphene, zircon, allanite and fluorite. Graphic quartz-microcline intergrowth textures dominate the groundmass, and K-feldspar phenocrysts consist of coarse perthite. Both features suggest epizonal characteristics. Rare plagioclase phenocrysts are embayed and corroded. Biotite is the dominant mafic phase, forming subhedral single crystals or aggregates with associated (usually relict) hornblende, which is locally poikilitic. Accessory minerals (sphene and zircon) are prominent, and fluorite occurs as interstitial material and discordant veinlets.

Field Relations, Geometry and Age. The southern boundary of the Mount Benedict Intrusive Suite is marked by a narrow belt of strongly deformed felsic volcanic rocks that is probably bounded by faults associated with the Benedict fault zone. In the east, it is bounded by the Tukialik granite of the Strawberry Intrusive Suite, which it is presumed to intrude. The map pattern suggests dextral displacement across a fault cutting through the suite, which is here interpreted as the continuation of the Adlavik Brook fault zone. The nature of the western contact with the volcanic rocks east of Stag Bay is unknown. The distribution of units within the suite suggests a crude layering or zonation. Most of the gabbro and diorite occurs at the edges of the suite or at relatively low elevations, whereas the syenite and quartz syenite is mostly restricted to the higher peaks. Much of the intermediate ground is dominated by the most abundant syenite to syenomonzonite unit. The small-scale compositional and textural variations within some outcrops are taken to indicate a gradational relationship between the different units. However, it must be stressed that most of the sampling and mapping in the Benedict Mountains was conducted by helicopter, and no detailed traverses were conducted.

Brooks (1982) obtained a Rb–Sr whole rock isochron suggesting an age of 1625 ± 50 Ma for syenite at Mount Benedict, but alluded to possible disturbance, as most samples had very high Rb/Sr ratios. U–Pb zircon data from two near-by localities (Kerr *et al.*, 1992) are slightly discordant, and indicate an age of 1649 ± 3 Ma. The Mount Benedict and Adlavik Intrusive suites are thus of essentially the same age.

Monkey Hill Intrusive Suite

Definition and Distribution

Monkey Hill Intrusive Suite (Kerr, 1988b) is a new, formal name proposed for several discrete, small, epizonal

plutons located in the Kaipokok Bay–Makkovik Bay area (Figure 6); it corresponds to parts of Units 28a and b of Gower *et al.* (1982). The type locality (referred to below as the 'main body') is at Monkey Hill, near Makkovik. All of these plutons intrude the Upper Aillik Group, and all consist of similar fine-grained, leucocratic monzogranite and granite. Some features of the suite are illustrated in Plate 18. The various plutons are probably small stocks or cupolas connected to a larger body at depth. In a discussion of potential specialized granitoids, Kerr (1988a) included the similar Witchdoctor and Burnt Lake granites with this suite. In view of the distance between these units and the type locality, and some differences in petrography, these are treated separately here.

The Monkey Hill Granite is a small (< 50 km²) pluton that intrudes the Upper Aillik Group and foliated granitoid rocks of the Kennedy Mountain Intrusive Suite. The Duck Island granite is a small stock or cupola restricted to a small islet in Mark's Bight; however, numerous veins and sheets of similar material intrude the Long Island Quartz Monzonite within a 2 km radius of the island. The Round Pond granite (described recently by MacDougall and Wilton, 1987, and MacDougall, 1988), consists of two small bodies that intrude the Upper Aillik Group; one of these is associated with hydrothermal alteration and mineralization. The Little Monkey Hill granite forms a prominent peak about 12 km east of the main body, and intrudes the Upper Aillik Group; dykes and veins associated with this body also cut mafic rocks of the Adlavik Intrusive Suite. The Bent's Cove granite intrudes metasedimentary rocks of the Upper Aillik Group. The Kidlaluit granite occupies most of Kidlaluit Island, and includes large blocks of coarse gabbro that resemble those of the Adlavik Intrusive Suite. Contacts of all bodies are sharp, intrusive interfaces characterized by stoping and net-veining of the country rocks. The relationship with the Adlavik Intrusive Suite gabbro suggests that the Monkey Hill Intrusive Suite is younger than ca. 1650 Ma.

Petrology

All members of the Monkey Hill Intrusive Suite are dominated by grey to buff or pink, fine to medium grained, faintly porphyritic, leucocratic, biotite–chlorite monzogranite, granite and (locally) alkali-feldspar granite. These are generally homogeneous, and lack inclusions except near contacts. The Duck Island and Round Pond granites, and parts of the Kidlaluit granite, are locally pegmatitic and/or miarolitic. The main body at Monkey Hill contains xenoliths of a darker-coloured phase on Gull Island, but is otherwise remarkably homogeneous over 900 m of vertical relief. At the northern end of Kidlaluit Island, an earlier grey phase is cut by the dominant pinkish granite. 'Tuffisite' breccias consisting of granite clasts in a biotite-rich matrix are locally exposed around Makkovik Bay, and suggest exsolution of dissolved volatiles. Shallow emplacement is also suggested by the local occurrence of a very fine-grained feldspar porphyry of subvolcanic appearance in the main body, Bent's Cove granite, and associated with the Duck Island granite.

The circular-shaped body northeast of the Duck Island granite consists of graphic micropegmatite that forms a network of sheets and veins intruding the Upper Aillik Group. Although petrographically atypical of the suite, it is grouped with it on the basis of proximity to three other members.

In thin section, typical examples consist of quartz (20 to 35 percent), plagioclase (An_{15-25}; 30 to 50 percent), microcline (30 to 50 percent), biotite and chlorite (up to 4 percent in total), minor epidote, muscovite and rare garnet, sphene, zircon and fluorite. Plagioclase forms small (up to 5 mm), euhedral to subhedral laths that appear to have crystallized early and, although similar in size to other grains, impart a 'porphyritic' or 'speckled' appearance. They have saussuritized cores, and are locally zoned. Quartz is interstitial or graphically intergrown with microcline. Green or green-brown biotite forms dispersed crystals or aggregates, and is altered to chlorite along cleavage traces. In many samples, chlorite is the dominant mafic mineral. Epidote is common in chlorite-bearing variants, and locally displays an interstitial habit suggesting that it may have been a primary magmatic phase. Garnet has been observed only at the northern end of the Kidlaluit granite. Minor muscovite may be related to feldspar alteration.

Field Relations and Age

As noted previously, plutons assigned to the Monkey Hill Intrusive Suite intrude the Upper Aillik Group, foliated granitoid rocks of the Kennedy Mountain Intrusive Suite, and mafic rocks of the Adlavik Intrusive Suite. The latter relationship indicates a maximum age of ca. 1650 Ma.

Wanless *et al.* (1970) obtained a K–Ar age of 1625 ± 60 Ma from the Round Pond granite. A Rb–Sr isochron of 1520 ± 35 Ma from this body (D. Wilton and C.S. MacDougall, personal communication, 1988) is probably disturbed by hydrothermal activity related to mineralization. U–Pb zircon data from the main body (Kerr and Krogh, 1990; Kerr *et al.*, 1992) are discordant, but suggest an age of ca. 1650 to 1640 Ma. They are colinear with zircon data from other Labradorian plutonic rocks, suggesting that all are of broadly similar age.

Witchdoctor and Burnt Lake Granites

Definition and Distribution

The Witchdoctor and Burnt Lake granites occur in the southwest, located between the Benedict fault zone and an area of Upper Aillik Group volcanic rocks. The two units are similar in many respects, and the Burnt Lake granite is interpreted here as a fine-grained marginal or roof phase of the Witchdoctor granite. Some features of these units are illustrated in Plate 19.

Witchdoctor Granite

Definition and Extent. The Witchdoctor granite corresponds to Unit 26e of Gower *et al.* (1982), and to part of the 'Walker Lake Granite' of BRINCO geologists, which also included

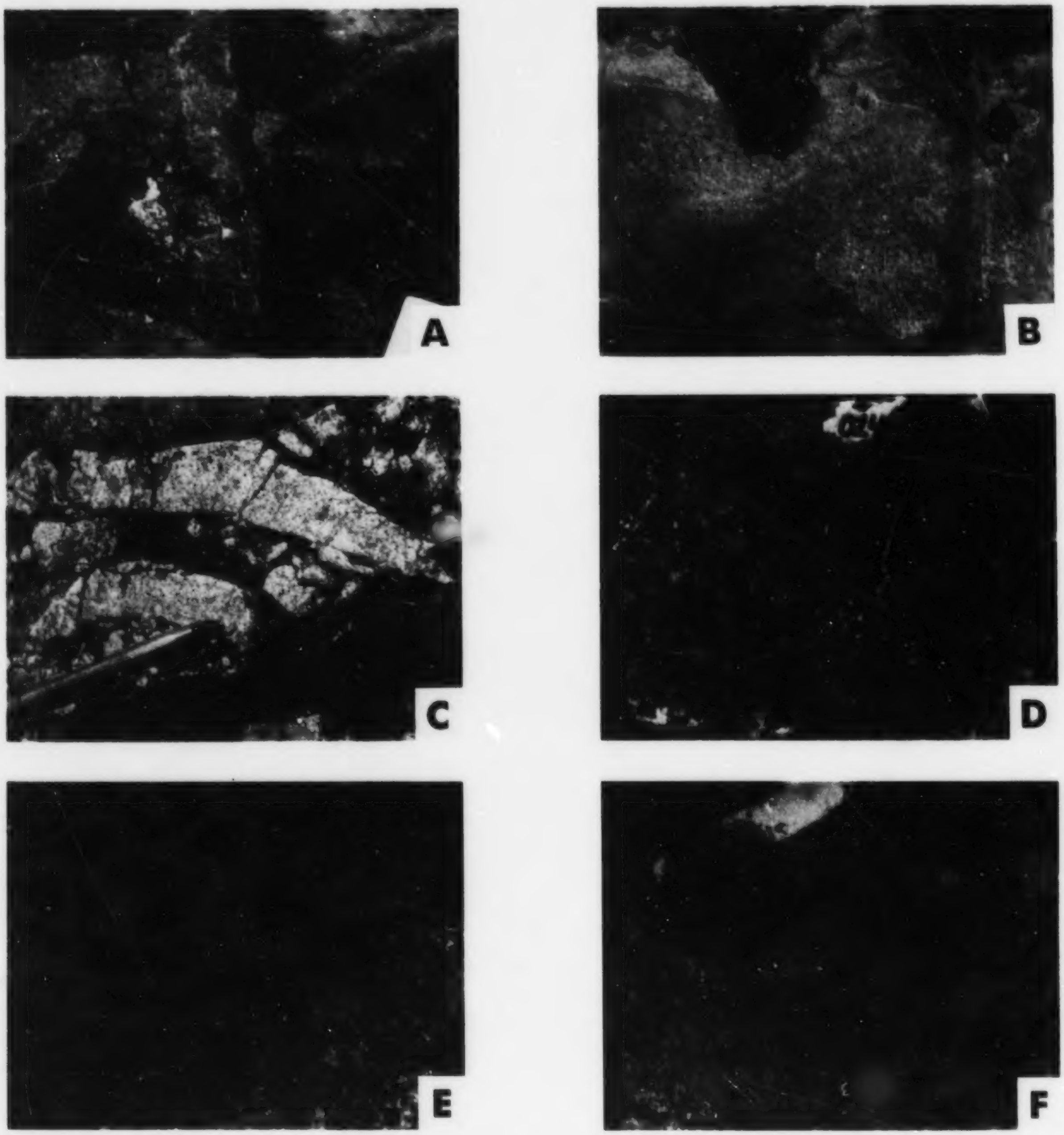


Plate 18. *Features of the Monkey Hill Intrusive Suite. a) Two phases of the Monkey Hill Granite; the dominant pink granite cuts a darker, grey-brown phase, Gull Island, Makkovik Bay. b) Vein correlated with Little Monkey Hill granite cutting gabbro of the Adlavik Intrusive Suite, Big Bight (large gabbro block about 30 cm across). c) Tuffisite breccia, with clasts of miarolitic granite and biotite–chlorite matrix, Makkovik Bay. d) and e) Typical Monkey Hill granites, from the main body. f) Molybdenite-bearing, slightly pegmatitic phase of the Duck Island granite, Duck Island.*

parts of the Otter Lake–Walker Lake granite. It was previously described as hornblende monzonite and granodiorite (Bailey, 1979; Gower *et al.*, 1982), but this description largely reflects its supposed correlation with the quite different granitoid rocks to the west.

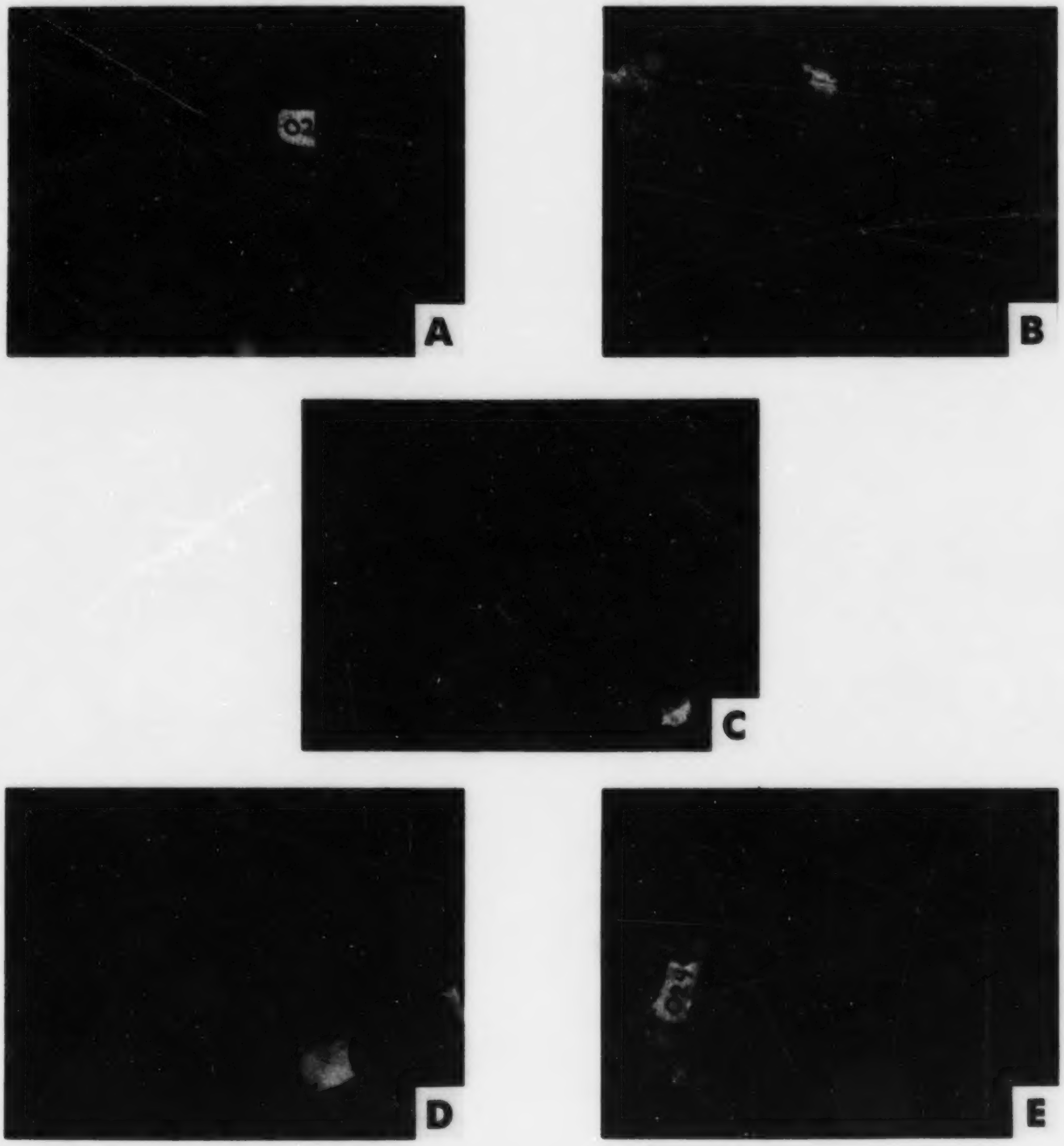


Plate 19. *Features of the Witchdoctor and Burnt Lake granites. a) and b) Typical examples of the Witchdoctor granite, showing variable recrystallization and deformation, Witchdoctor Lake area. c) and d) Foliated and unfoliated Burnt Lake granites, Burnt Lake area. e) Miarolitic Burnt Lake granite, adjacent to Burnt Lake molybdenite showing. Slabs stained for K-feldspar.*

Description. The unit is dominated by pink to white, medium to coarse grained, variably foliated, leucocratic biotite and biotite–muscovite monzogranite to alkali-feldspar granite. Most examples are homogeneous and equigranular, but recrystallization and deformation are widespread, and local east-trending fabrics are present.

In thin section, typical examples consist of quartz (25 to 40 percent), microcline (40 to 70 percent), plagioclase (An_{20}; 10 to 25 percent), biotite and muscovite (1 to 5 percent in total, biotite dominant), hornblende (relict), minor garnet, chlorite, and epidote, and accessory sphene, allanite and zircon. Quartz is extensively recrystallized and forms elongate

ribbon-like aggregates, although it locally retains a vestigial interstitial habit. Green-brown biotite is intergrown with lesser amounts of muscovite, forming aggregates parallel to foliations. Relict hornblende occurs locally in muscovite-poor variants, and chlorite occurs locally as an alteration product of biotite. Pale-pink garnet is a minor constituent of several samples; crystals are granular and cut by mylonitic zones.

Field Relations and Age. The Witchdoctor granite is poorly exposed throughout, and its contact relations with the Burnt Lake granite are unknown. Similarly, its relationship to the Otter Lake–Walker Lake granite, to the west, is completely obscured by drift. Brooks (1983) dated the Witchdoctor granite (termed 'Walker Lake Granite' at that time) at 1595 ± 34 Ma (Rb–Sr, whole rock) and 1632 ± 9 Ma (U–Pb, zircon).

Burnt Lake Granite

Definition and Extent. The Burnt Lake granite corresponds to Unit 24 of Gower *et al.* (1982), which was given the same name. These authors recommended that the name be abandoned in view of prior usage, but it has continued to be popular and is retained here. It is located between the Witchdoctor granite and the Upper Aillik Group.

Description. The Burnt Lake granite is dominated by white to pale grey or pink, fine to medium grained, equigranular, leucocratic monzogranite, granite and (locally) alkali-feldspar granite. It is generally homogeneous, and commonly has a sugary, recrystallized appearance; it is locally weakly foliated. Disseminated Mo mineralization is present in the contact zone of the granite, and it has also been linked to uranium–base-metal mineralization in adjacent country rocks (MacKenzie and Wilton, 1987).

In thin section, typical examples consist of quartz (20 to 40 percent), microcline (25 to 40 percent), plagioclase (20 to 50 percent), biotite and muscovite (up to 5 percent in total, mostly biotite), and accessory allanite, garnet and sphene. Most samples are recrystallized, and original igneous textures, except for relict microcline phenocrysts, are not readily discerned. Muscovite occurs both as intergrowths with biotite flakes of a similar size range, and as fine-grained fibrous aggregates of secondary appearance. It is absent in the more melanocratic variants. Minor garnet is present locally, but is less common than in the Witchdoctor granite.

Field Relations and Age. Bailey (1979) described contacts with the Upper Ailik Group as gradational, a reflection of the similarity between fine-grained granite and sugary, recrystallized rhyolite. However, MacKenzie and Wilton (1987) describe sharp intrusive contacts from several localities. Rb–Sr data presented by MacKenzie and Wilton (1988) give a 1548 ± 90 Ma errorchron, which they suggested to be disturbed by Grenvillian events. This could, however, also be interpreted as a reflection of post-crystallization hydrothermal activity (cf. Walraven *et al.*, 1986).

Otter Lake–Walker Lake Granite

Definition and Extent

This is a regionally extensive granite unit in the southwest (Figure 6), which extends for 50 to 75 km beyond its western edge. It corresponds to Unit 32 of Ryan (1984), which he grouped with spatially associated muscovite–biotite granites (Crooked River Granite) to form the Nipishish Lake Intrusive Suite. The Crooked River Granite does not outcrop within the study area. Descriptions below apply only to quartz monzonite, monzogranite and granite within the study area.

Description

The Otter Lake–Walker Lake granite is dominated by grey to pink or green-white, medium to coarse grained, porphyritic to seriate, biotite–hornblende quartz monzonite, granodiorite and monzogranite. Melanocratic dioritic variants occur locally. Some features of the unit are illustrated in Plate 20. Both K-feldspar and plagioclase phenocrysts are present; in most examples, the former are larger, up to 3 to 5 cm in size. Characteristic features include pale-green saussuritized plagioclase, and blue-grey interstitial quartz, both noted also by Ryan (1984).

In thin section, typical examples consist of quartz (15 to 30 percent), microcline (30 to 50 percent), plagioclase (An_{25-40}; 20 to 50 percent), biotite and hornblende (3 to 8 percent, biotite dominant), clinopyroxene (rare, relict), sphene (locally up to 2 percent), and accessory allanite, zircon and apatite.

Recrystallization is most intense in the south and near to inferred faults; many samples in the north are undeformed and retain good igneous textures, such as interstitial quartz crystals. Microcline phenocrysts are finely perthitic and locally have rims of sodic plagioclase. Plagioclase phenocrysts display normal zonation, and contain saussuritized centres. Green or green-brown biotite is the dominant mafic silicate, associated with lesser green hornblende. Relict clinopyroxene, altered to hornblende, is present only rarely. Sphene is abundant in most samples, and locally occurs in amounts comparable to hornblende or biotite. It forms euhedral or subhedral crystals up to 3 mm in size, and in places displays a clear interstitial habit. Epidote and/or chlorite are important as alteration products of plagioclase, and are the dominant mafic silicates in the most strongly deformed samples.

Field Relations and Age

Ryan (1984) describes an intrusive contact between granodiorite assigned to this unit and metasedimentary rocks of the Upper Aillik Group in the Walker Lake area. The contact with the syntectonic Makkovikian Melody Granite corresponds with an inferred fault zone. The relationship between this unit and the Witchdoctor granite, which outcrops to the east, is unknown.

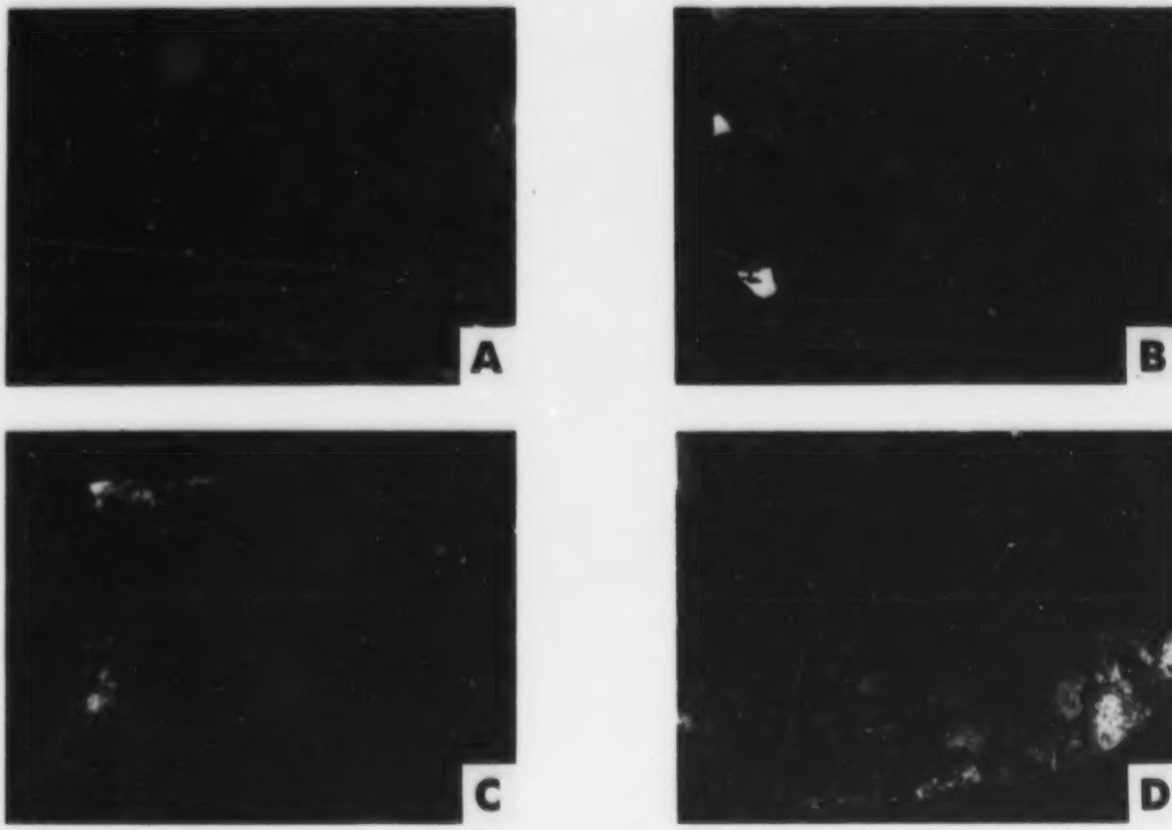


Plate 20. *Features of the Otter Lake–Walker Lake granite. a) to d) Typical quartz monzonite to monzogranite samples, showing variable recrystallization and deformation, but with well-preserved igneous textures. All samples from the Walker Lake area. Slabs stained for K-feldspar.*

Kontak (in Ryan, 1984) obtained a Rb–Sr errorchron suggesting an age of 1550 ± 55 Ma from granite at Walker Lake. This is similar to Rb–Sr ages from the Witchdoctor and Burnt Lake granites, and is probably disturbed. U–Pb zircon data (Kerr and Krogh, 1990; Kerr *et al.*, 1992) are concordant at 1647 ± 2 Ma.

UNCLASSIFIED PLUTONIC ROCKS

This association comprises two small, largely undeformed units, within the Makkovik Structural Province, and a large area of granitoid gneisses that underly the Grenville Province south of the Benedict fault zone (Figure 10). Kerr (1989a) also included the Freshsteak and Noarse Lake granitoids, and the Stag Bay granodiorite, in this category. However, Rb–Sr whole-rock and U–Pb zircon data indicate that these units belong to the Posttectonic Makkovikian association.

Jeanette Bay Quartz Syenite

This minor unit is located in the Benedict Mountains south of Jeanette Bay. It corresponds to Unit 22 of Gower (1981), and was considered by him to be related to the Mount Benedict Intrusive Suite (Unit 21 of Gower, 1981). However, it mostly lacks the distinctive textural characteristics of these rocks, and is also geochemically distinct. It is dominated by pink to grey, coarse-grained, variably K-feldspar porphyritic quartz syenite to granite. Contact relationships are unknown. It is commonly massive, but locally appears slightly foliated and/or sheared. Microcline is the most common phenocryst phase. Plagioclase cores in sporadic pseudorapakivi phenocrysts are commonly zoned and saussuritized. In many samples, the mafic mineral assemblage has been retrogressed to chlorite–epidote–sphene aggregates. The groundmass is plagioclase-rich compared to the K-feldspar and quartz groundmass typical of the adjacent Mount Benedict Intrusive Suite, a contrast previously noted by Gower (1981). In general, it appears more recrystallized than the normally pristine rocks of the Mount Benedict Intrusive Suite.

Thunder Mountain Syenite

This small body occurs southwest of Stag Bay, between the Benedict fault zone and another northwest-trending fault

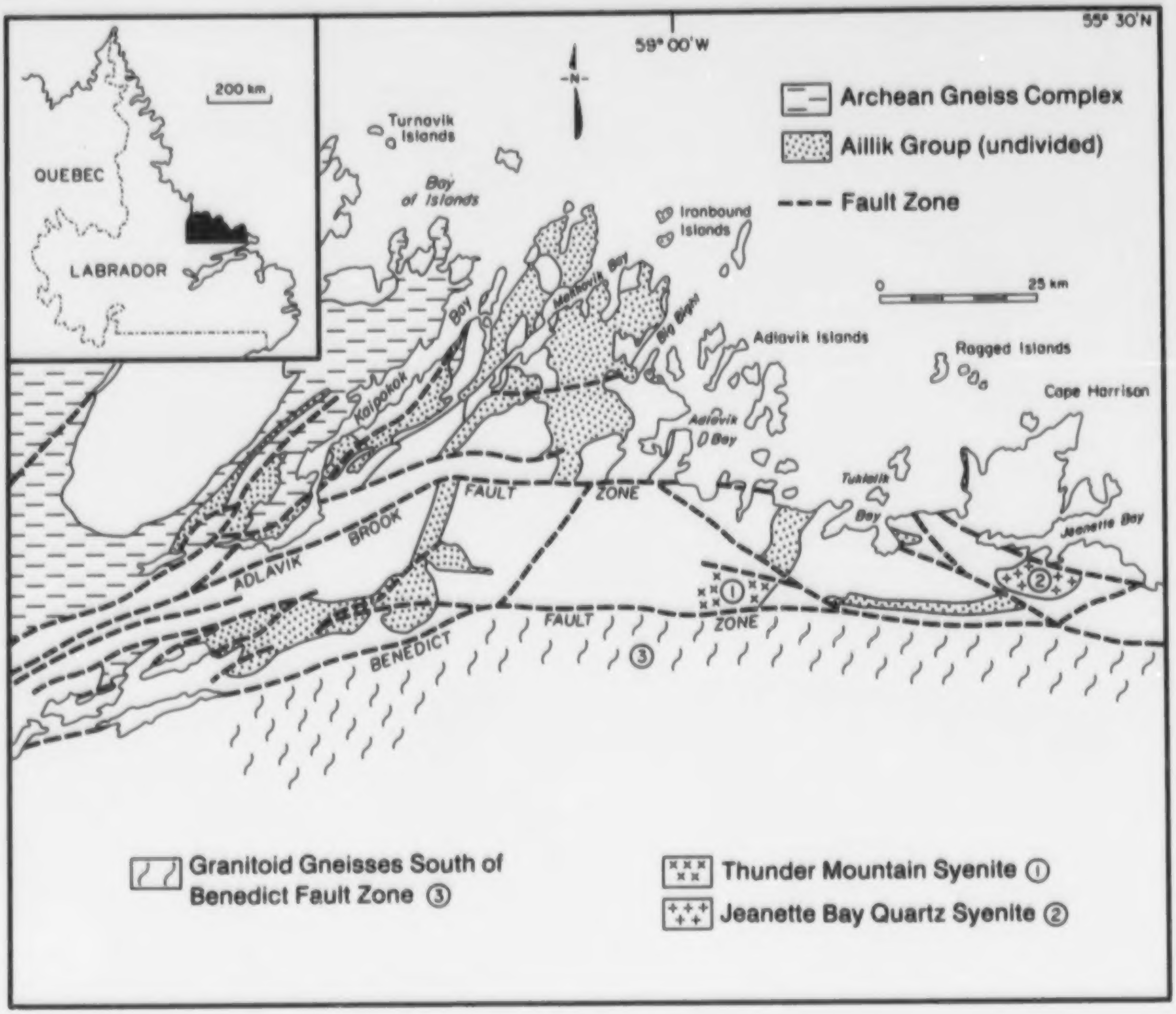


Figure 10. *Summary map illustrating the distribution and extent of unclassified plutonic units.*

mapped by Gower (1981). It is equivalent to a portion of Unit 26 of Gower *et al.* (1982). It consists mostly of coarse grained, massive, K-feldspar porphyritic, hornblende monzonite, syenite, quartz syenite and granite. It is in (inferred) fault contact with the Stag Bay granodiorite and part of the Mount Benedict Intrusive Suite to the north, and with granitoid gneisses of the Grenville Province to the south. Eastern and western contact relations are unknown. In most areas, it is massive and undeformed, and is characterized by distinctive interstitial blue quartz grains. Large microcline phenocrysts (up to 5 cm diameter) have both simple and polysynthetic twinning, possibly indicating original orthoclase phenocrysts. Zoned plagioclase phenocrysts are locally present. Green clinopyroxene is a local relict phase, and is altered to hornblende and a red-brown phase.

Granitoid Gneisses South of the Benedict Fault Zone

South of the Benedict fault zone (Figure 10), all units exhibit moderate to intense east-trending foliations attributed to Grenvillian deformation, and many are gneissic or banded in texture. These rocks have not been studied in detail in this project, and are thus grouped here as a single map unit. This composite unit clearly consists of a variety of rock types in highly variable states of deformation. All areas south of the Benedict fault zone are poorly exposed (excluding river courses), and the most prominent outcrops are invariably the Michael Gabbro intrusions. Characteristics and relationships of different granitoid gneiss variants in this part of the Grenville Province are thus very poorly known.

The northern boundary of the gneissic terrane is the Benedict fault zone itself, although some areas north of the generally accepted position of this fault exhibit deformation of equivalent intensity, and are included in the gneiss unit. The Benedict fault is a composite zone that cannot be represented adequately by a single line on a map. In the west, it is described by Bailey (1979) as a broad zone of mylonitization displaying a subvertical lineation. The zone is well exposed in Big River, where it is a composite feature consisting of a broad zone of intense deformation (up to 1 km in width) within which occur a large number of individual mylonite zones, dipping at 40 to 70° south, with steeply plunging lineations upon foliation surfaces. In the Benedict Mountains, Gower (1981) described it as a south-dipping reverse fault displaying evidence also of dextral motion. The contrast in deformation state across the fault is extreme in this area, and it appears to be a narrower, more tightly focussed structure than in the west.

South of the main fault zone, a number of discontinous cataclastic and mylonitic zones occur within the granitoid gneisses. Fine-grained, strongly foliated granitoid gneisses form concordant layers within coarser foliated granitoids; these may be original textural variants, but more likely represent mylonitic zones developed on a hand-sample or outcrop scale. On a regional scale, these are interpreted to have an anastomosing pattern, similar to that seen in many hand specimens that have relict porphyritic textures.

The granitoid gneisses appear (at least locally) to resemble adjacent rock types north of the Benedict fault zone. For example, in the area south of the Big River Granite, they comprise pink or buff, coarse-grained, cataclastic to mylonitic, augen-textured rocks that have a composition approximating biotite–hornblende granite or alkali-feldspar granite. Vestiges of pseudorapakivi texture are present in the least deformed examples, and they contain blue-green hornblende typical of the Big River Granite. A similar relationship was noted by Gower (1981) in the eastern Benedict Mountains, where megacrystic granitoids and augen gneisses occur north and south of the fault respectively. South of the main Benedict Mountains massif, the contrast in deformation state across the fault is extreme, and occurs principally across faults that bound a narrow metavolcanic enclave. The rocks south of the fault zone in this area comprise a heterogeneous mixture of two contrasting rock types. Coarse-grained biotite–hornblende augen granitoids display relict K-feldspar porphyritic textures, and characteristically contain blue-green hornblende. The mafic assemblage is variably retrogressed to sphene and epidote. These rocks are interspersed with fine to medium grained, equigranular to locally banded, leucocratic, granitoid gneisses containing minor biotite and muscovite. These two variants do not neccessarily represent discrete rock types; Gower (1981) suggests that they may represent variable deformation and metamorphism of a common protolith, although the presence of muscovite implies some compositional contrasts. Gower (1981) distinguished a strongly deformed augen gneiss of monzonitic to syenitic composition close to the fault zone, and also two areas of supracrustal rocks, which he considered to be of volcaniclastic origin.

GRANITE-RELATED MINERALIZATION[1]

INTRODUCTION

This section, which draws heavily upon a Geological Survey of Canada paper authored by Derek Wilton (Wilton, *in press*), provides an overview of mineralization within the study area that is hosted by, or considered to be spatially and genetically linked to, some of the granitoid intrusive rocks described earlier. The study area has a long history of sporadic exploration, and many of the mineral occurrences were initially described in exploration company reports, many of which remain confidential. Much of this industry work is summarized by Mineral Occurrence Data System (MODS) files for map sheets 13O, 13J and 13K, compiled by Kerr (1982). Summaries of mineralization in various parts of the Central Mineral Belt were also published by Gandhi (1978), Gower *et al.*, (1982) and Ryan (1984). From 1984 to 1988, Derek Wilton of the Department of Earth Sciences/Centre for Earth Resources at Memorial University, in St. John's, co-ordinated a multidisciplinary study of mineralization in the Central Mineral Belt, as a research contract funded by the Canada–Newfoundland Mineral Development Agreement. A range of geological, geochemical and isotopic studies of Central Mineral Belt deposits have been conducted, partly in conjunction with thesis studies by MacDougall (1988), North (1988) and MacKenzie (1991); results have been published by both the Geological Survey of Canada and the Newfoundland Department of Natural Resources, and also as unpublished contract reports. Much of the material that follows, especially in relation to recent description and interpretation, is drawn from this major piece of work by Derek Wilton and several of his graduate students, notably Craig MacDougall and Leonard MacKenzie. The senior author (of this section) is indebted to these individuals for allowing some aspects of their valuable work to be summarized, and they have coauthored this chapter.

Review of Exploration and Development

Gower *et al.* (1982) presented a review of activity in the eastern Central Mineral Belt, and Ryan (1984) summarized activity in the central and western portions. In the study area,

[1] Authors: A. Kerr, D. Wilton, C. MacDougall and L. MacKenzie

the key event took place in 1954, when pitchblende was discovered in a narrow veinlet at a locality that henceforth acquired the appropriate name 'Pitch Lake'. The British Newfoundland Corporation (BRINCO) subsequently located a small, high-grade uranium deposit (Kitts Prospect) in the Lower Aillik Group in 1956 and, for the next 30 years, dominated exploration activity in the eastern Central Mineral Belt. Through most of this period, BRINCO held a mineral rights concession negotiated with the Newfoundland government, which covered most of the area from Kaipokok Bay to Adlavik Bay and Big River. In 1959, a significant Mo deposit was found in the Upper Aillik Group at Aillik Bay, and underwent extensive evaluation as part of a BRINCO-AMAX joint venture. In the early 1960s, polymetallic, dominantly vein-hosted, mineralization was discovered in Upper Aillik Group metavolcanic rocks at Round Pond, in the Makkovik area, and evaluated for several years. However, none of these prospects proved economic under market conditions prevalent at the time.

Interest in uranium returned in the late 1960s, and inland areas of the BRINCO concession received their first detailed assessment. In 1967, the large, low-grade, Michelin uranium deposit, and a number of related prospects were discovered in the Upper Aillik Group. Intensive uranium exploration in both the Lower and Upper Aillik groups throughout the area continued for 10 years or so, and development proposals for both Kitts and Michelin were submitted in 1979. Approval was witheld by the government, mostly on environmental grounds, and deterioration in the uranium market rapidly reduced corporate enthusiasm for the project. In the late 1970s and early 1980s, a BRINCO-Placer Development joint venture led to some minor uranium exploration in the Makkovik Area, and BRINCO conducted some small-scale exploration in the Burnt Lake area in the mid 1980s.

Much of the area essentially lay dormant during the 1980s, and BRINCO's concession rights eventually expired; however, most of their significant prospects were protected by conversion to mining leases. In 1984, a number of showings were sampled and analyzed for precious metals (Wardle and Wilton, 1985). Two vein-type occurrences, located northeast of Makkovik, yielded significant Au and Ag values. A number of claims were subsequently staked by Newfoundland-based interests, and some limited evaluation work was carried out from 1985 to 1987 by COMINCO, Cuvier Mines, and MARITEC (the latter acting on behalf of J.Lundrigan and Associates). No significant exploration activity took place in 1988 or 1989.

Overview of Mineralization Patterns

If abundance of known mineralization is used as a first criterion, the Aillik Group (both lower and upper divisions) is the most important host assemblage in the eastern Central Mineral Belt, containing over 90 percent of known mineral occurrences. Gower *et al.* (1982) proposed that mineralization could be grouped spatially into three belts (Figure 11). Although ideas on the genesis of individual deposit types have been revised by more recent work (Wilton, *in press*), these remain valid in general terms. Wilton and Wardle (1987) and Wilton (*in press*) use a slightly modified terminology; their 'Makkovik Zone' corresponds to the Aillik–Makkovik Belt and Round Pond–Ford's Bight–Big Bight areas described below, and their 'Michelin Zone' to the Michelin–White Bear Mountain belt described below.

Kitts–Post Hill Belt

The Kitts–Post Hill Belt is mostly located within the folded supracrustal sequence of the Lower Aillik Group; metasedimentary rocks of this sequence are the dominant host rocks, and important prospects are 'stratiform' (but not neccessarily syngenetic) uranium showings, with lesser disseminated and massive sulphide zones. Wilton (*in press*) consider deposit geometry to be stratiform only on a regional scale, and state that individual mineralized structures are variably discordant. Evans (1980) and Gower *et al.* (1982) describe these deposits in some detail; Gandhi (1978) advocated a 'syngenetic' origin, but subsequent workers have preferred epigenetic–hydrothermal models in which the Lower Aillik Group metasedimentary rocks represent a favourable precipitation site (Evans, 1980; Gower *et al.*, 1982; Wilton, *in press*) characterized by abundance of reductants such as carbon or ferrous iron.

Michelin–White Bear Mountain Belt

This diffuse zone of showings and prospects is localized in variably preserved felsic volcanic and volcaniclastic rocks of the Upper Aillik Group. It includes the important Michelin deposit, containing over 6 million tonnes of 0.13 percent U_3O_8 (BRINCO estimate, quoted by Gower *et al.*, 1982). Uranium mineralization at Michelin and similar prospects consists of disseminated to veinlet/fracture-hosted pitchblende and/or uraninite, and is regionally subconcordant to stratigraphy. In detail, however, mineralization (and associated wall-rock alteration) transgress bedding and unit boundaries. Epigenetic–hydrothermal models have been preferred by most workers; Gower *et al.* (1982) also raised the possibility that volcanism and felsic mineralization may have been partially synchronous on a regional scale, and drew analogies with 'volcanogenic' uranium in caldera environments of the southwestern United States of America and adjacent Mexico (e.g., Platt, 1980).

A group of U occurrences in the Burnt Lake area, just west of White Bear Mountain, have somewhat different characteristics in that they are associated with Pb, Zn, Cu, F and Ag (MacKenzie and Wilton, 1987).

Aillik–Makkovik Belt

Gower *et al.* (1982) suggested that mineral occurences forming a linear belt extending some 30 km from Cape Aillik to near Makkovik were distinct from the belts described above in that there appeared to be an association between U and Mo–F mineralization. The most significant deposit in this area is the Aillik molybdenum prospect, containing 2 million

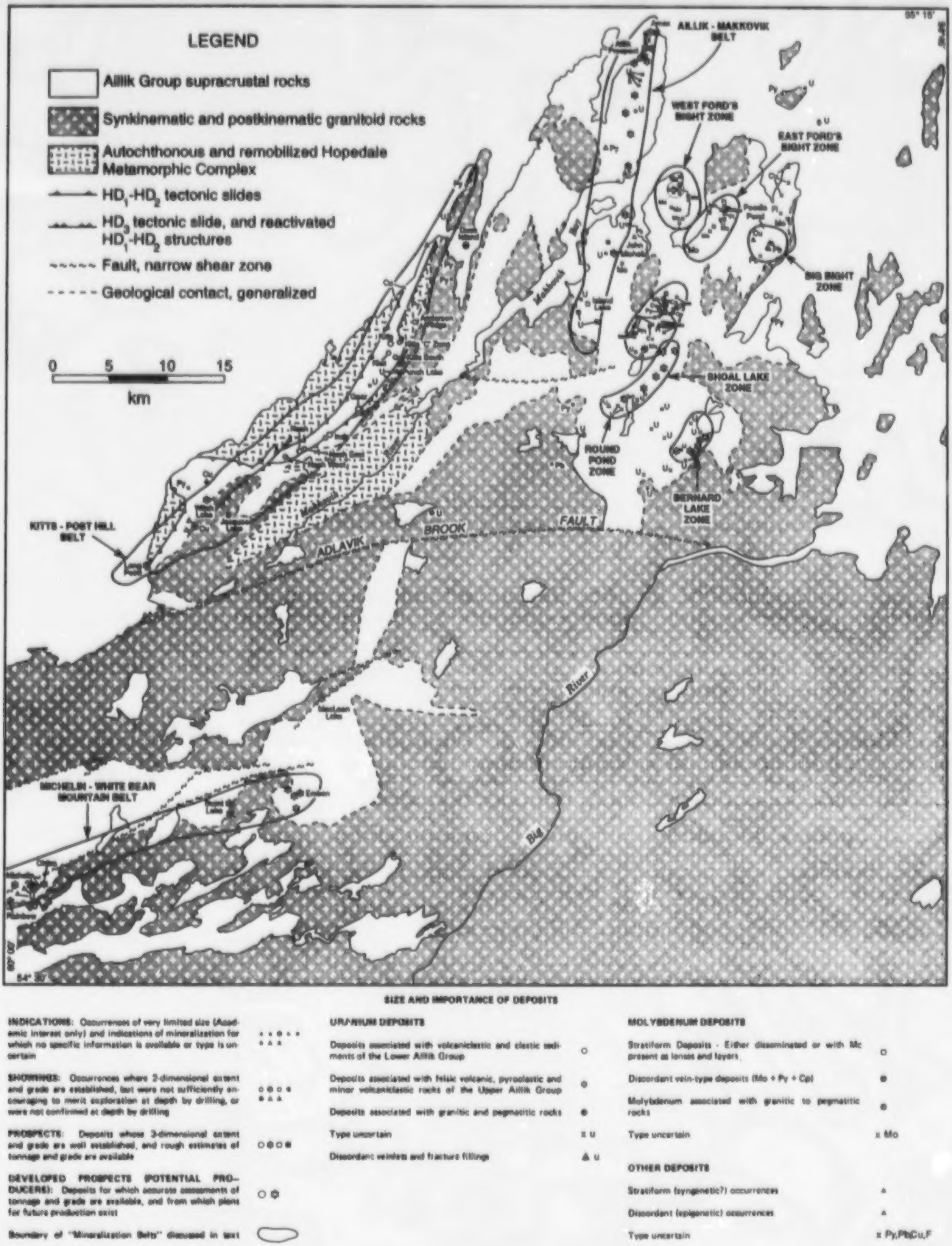


Figure 11. *Distribution of mineral occurrences of all types, and "belts" of mineralization in the Kaipokok Bay–Big River area, forming the western 80 percent of the study area (reproduced from Gower* et al.*, 1982).*

tonnes of around 0.25 percent MoS_2 (BRINCO estimate, quoted by Gower *et al.*, 1982). At this, and other prospects, low-grade U mineralization also occurs sporadically. Higher grade U mineralization is also present in isolation, for example, at the Black Hat and A-7 showings (Figure 12). As in the other metallogenic belts, mineralization is commonly subconcordant on a regional scale, but mineralized structures are variably discordant. Felsic metavolcanic rocks of the Upper Aillik Group form the dominant host assemblage.

Round Pond–Ford's Bight–Big Bight Area

The three zones can legitimately be described as 'belts', as they have an elongate form. Also, a wide zone of highly varied, widely distributed mineralization present south and east of Makkovik has a much less regular form (Figure 11). Commodities include abundant U, as in other areas of the Aillik Group, but also Cu, Mo, Pb, Zn, F and Ag. There is also a great diversity of form in these scattered occurrences; many are crosscutting quartz or carbonate-matrix veins, and the 'pseudo-stratiform' aspect so typical of other areas of the Aillik Group is less marked. Many of these prospects provide the best evidence for granite-related mineralization processes, and several are discussed in more detail in the following section.

MINERALIZATION ASSOCIATED WITH GRANITOID INTRUSIVE ROCKS

Ryan (1977) and Gower *et al.* (1982) both speculated that the granitoid intrusive rocks of the eastern Central Mineral Belt may have some bearing on the genesis of some mineralization hosted by the Upper Aillik Group, particularly in the Round Pond–Ford's Bight–Big Bight area. The work of Derek Wilton and research students since 1984 has lent considerable support to this concept, and has broadened the range of mineralization that may be genetically related to felsic magmatism. In this section, some of the more important examples are summarized. Figure 12a,b shows the distribution of the more important granite-related mineral occurrences currently recognized in the area.

Endocontact Mineralization

Mineral occurrences that are hosted within granitoid intrusions themselves are rare compared to those hosted within the country rocks around their margins (exocontact mineralization, see below). However, they provide important evidence for a link between the granitoid rocks and epigenetic mineralization of similar type in the Upper Aillik Group.

Duck Island Showing (Mo)

The most spectacular endocontact showings consist of molybdenite. Heavily disseminated molybdenite in the form of rosettes associated with pyrite, minor chalcopyrite and possibly bornite occurs in a fine to medium grained highly miarolitic to vuggy leucogranite on the east shore of Duck Island, covering an area of some 100 to 200 m². The island is a small skerry less than 500 m in diameter, located in Mark's Bight, just south of Long Island (Figure 12b). Minor amounts of disseminated pyrite occur sporadically all over the island. Grab samples of representative material from the showing contained up to 0.5 percent Mo, but only negligable amounts of Pb, Cu, Zn and Sn.

Previous mapping (Gower *et al.*, 1982) grouped Duck Island as part of the foliated Long Island Quartz Monzonite. However, examination during this project shows that the island consists of fine- to medium-grained monzogranite typical of the Monkey Hill Intrusive Suite, a high-level, leucocratic granite association of Labradorian (1650 to 1640 Ma) age. Continous exposure of the granite is restricted to the island itself, but a network of fine-grained-granite dykes, veins and sheets disrupts the Long Island Quartz Monzonite up to 2 km from Duck Island. The Duck Island granite, as termed here, is interpreted as a small cupola or satellite intrusion of this suite.

Burnt Lake Showing (Mo)

Disseminated molybdenite mineralization, locally achieving spectacular grades, is hosted by the Burnt Lake granite adjacent to its intrusive contact with the Upper Aillik Group. Flakes and rosettes are heavily disseminated over an area of about 50 to 100 m². There is very little associated pyrite in this showing, in contrast to the Duck Island locality. The showing, reported initially by Bailey (1979), is about 1 km from the Burnt Lake uranium showings. MacKenzie and Wilton (1987) and MacKenzie (personal communication, 1994) view the showing as magmatic–hydrothermal in origin, and report that geochemical zonation (notably an increase in SiO_2) occurs toward the granite contact. The Burnt Lake granite is a weakly peraluminous leucogranite, probably of Labradorian age, that resembles the Monkey Hill Intrusive Suite in both petrology and geochemistry.

Other Endocontact Mo Occurrences

A number of other minor Mo occurrences are shown within granitoid rocks on the mineral occurrence map, but many of these are essentially undocumented. There are problems with locating these minor showings in the field as their marked locations vary considerably on BRINCO maps, with resultant uncertainty on Mineral Occurrence maps compiled from this data. MacDougall and Wilton (1987) report minor Mo in two granite stocks at Round Pond which are grouped with the Monkey Hill Intrusive Suite, but no Mo has so far been reported from the main body. Visible Mo is similarily lacking from the main part of the Strawberry granite, but this unit does contain irregular pyritic zones near its eastern contact which crosscut the granite host and contain elevated (25 to 50 ppm versus a background of <5 ppm) levels of Mo.

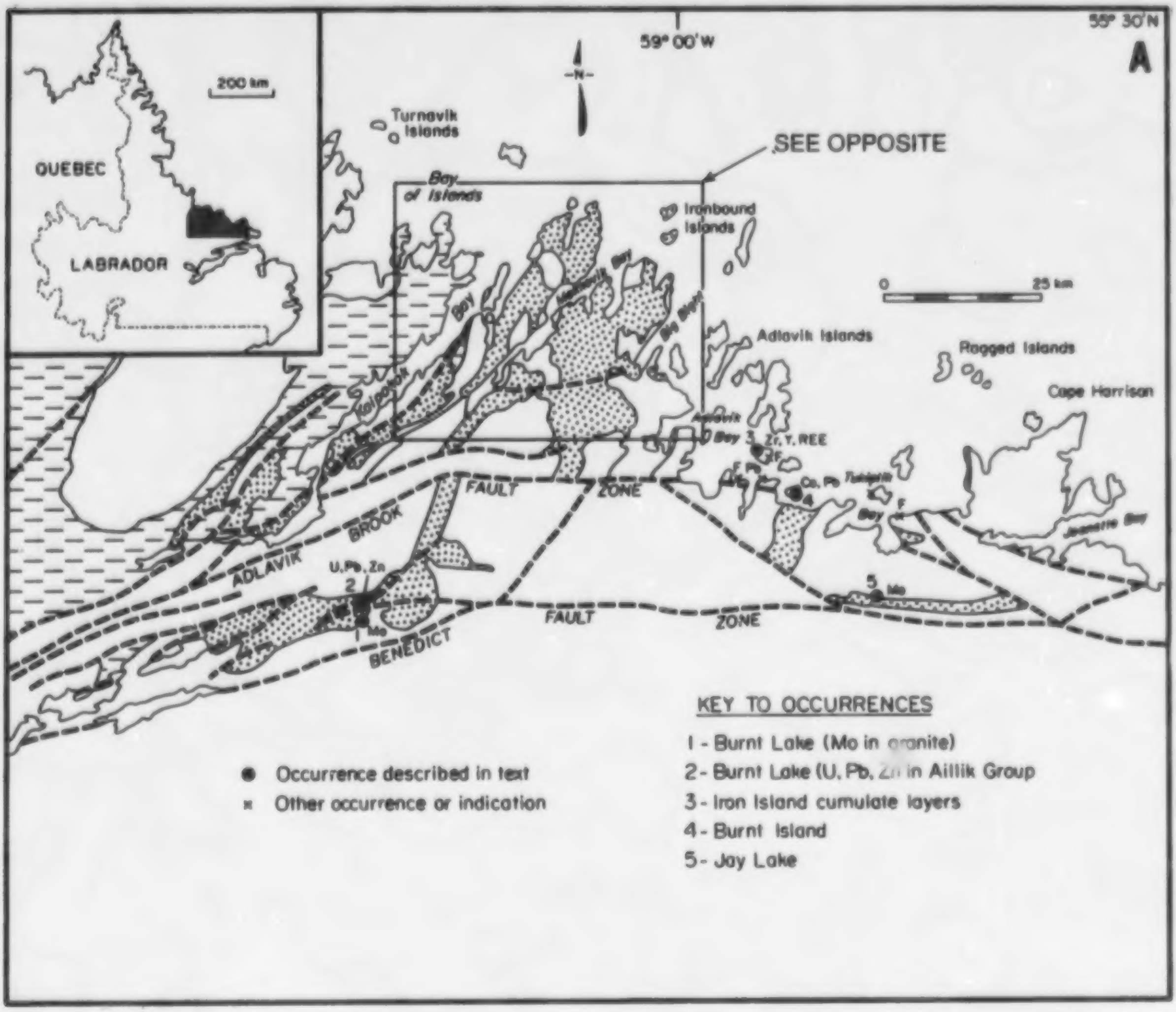


Figure 12. *a) Distribution and types of granite-related mineral occurrences in the study area. b) This is an enlargement of the Kaipokok Bay–Adlavik Bay area, where the largest concentrations occur. Compiled MODS files and maps and recent work by Wilton (in press). Note that the locations of many smaller occurrences are approximate.*

Molybdenite flakes occur in several coarse-grained, fluorite-bearing pegmatites on the west side of Ford's Bight, and also on the shore of Wild Bight. These pegmatites resemble the coarser variants of the Cape Strawberry granite and are viewed here as apophyses of the main pluton (Wilton and Wardle, 1987; Kerr, 1987).

Burnt Island Showing (Cu–Pb)

Minor Cu–Pb mineralization was discovered at the eastern end of Burnt Island during follow-up work in the Dog Islands granite (grouped here with the Strawberry Intrusive Suite). The showing consists of disseminated chalcopyrite and galena associated with the margins of fine-grained aplitic veins, which cut the coarse-grained granite. Grab samples of sporadic mineralization contain up to 2900 ppm Pb and 5000 ppm F, but only 500 ppm Cu and Zn respectively. One sample also contained 116 g/t Sn. The most intense mineralization is at the margins of the veins, but it is sporadic in extent and grade. Other Cu–Pb showings are reported from this unit, and also from the October Harbour granite (data in MODS files and BRINCO maps). These were not located during this study, and are presumably of minor extent.

Disseminated Fluorite Occurrences

Disseminated fluorite and, more rarely, thin fluorite veinlets, are common in granites of the Strawberry Intrusive Suite, and also within the Lanceground Intrusive Suite and the syenite–granite unit of the Mount Benedict Intrusive Suite. Fluorite 'showings' located in Figure 12a,b are simply locations where more than the normal amounts of fluorite

Figure 12. *b) This is an enlargement of the Kaipokok Bay–Adlavik Bay area, where the largest concentrations occur. Compiled MODS files and maps and recent work by Wilton* (in press). *Note that the locations of many smaller occurrences are approximate.*

were observed; interstitial purple fluorite is present in most samples of the Strawberry Intrusive Suite. Disseminated fluorite is also widespread in foliated leucocratic granites of the Kennedy Mountain Intrusive Suite.

Radioactive Zones and Uranium Mineralization

A large number of radioactive occurrences are illustrated on BRINCO and MODS mineral occurrence maps. The characteristics of many of these are essentially unknown, but Wilton (personal communications, 1986, 1987) reports that fluorite is commonly also present, and many examples prove to be pegmatitic segregations upon examination. A showing at Island Pond is a pegmatite-like body adjacent to the contact of the Monkey Hill Granite (D. Wilton, personal communication, 1986).

Uranium mineralization may also be present within the foliated syntectonic Makkovikian Melody Granite. High-grade pitchblende mineralization (up to 20 to 30 percent U_3O_8 was discovered by BRINCO in boulders near Melody Hill itself. Some of the mineralized boulders resemble hematized

granitoid rocks. Weak U mineralization is present within the granite itself in one location and is there associated with similarly intense hematization. Despite extensive prospecting and glacial studies, the source of the high-grade float was never located. Recent work by Batterson *et al.* (1987) suggests that the glacial history of the Melody Hill area may be more complex than previously supposed, and that a more distal source is possible.

Indications of Zr–Y–REE Mineralization

Biotite-rich zones of probable cumulate origin were identified in the Strawberry Intrusive Suite, most notably in the Cape Strawberry granite and the Dog Islands granite. These contain relatively high concentrations of rare metals and REE, up to 4700 ppm Zr, 400 ppm Y, 1300 ppm La and 1200 ppm Ce. A routine sample from Tukialik granite, in which no layering was observed, contained over 4500 ppm Zr. A dyke of fine- to medium-grained granite that cuts foliated agmatites near Adlavik Bay also contains over 4500 ppm Zr and 160 ppm Y. This minor intrusion is probably related to the nearby Lanceground Hills granite, which is commonly anomalous in Zr. Although the quantities of material represented by these occurrences are small, they illustrate potential for more significant concentrations of these elements. Cumulate layers of this type, with enhanced Zr, Y and REE contents, represent a type of 'primary' magmatic mineralization that has not previously been reported.

Exocontact Mineralization

A large number of mineral occurrences within the Upper Aillik Group, particularly around Makkovik, have characteristics that suggest that they are genetically related to nearby or subjacent plutons.

Round Pond Polymetallic Vein System

The Round Pond area, a few kilometres south of Makkovik village, provides some of the best examples of epigenetic vein-type mineralization of granophile aspect. The most complete study of these prospects has been conducted by MacDougall (1988), upon whose M.Sc. thesis the following summary is based.

A large number of gossan zones and mineralized structures occur within the area (Figure 13); these bear a clear spatial relationship to one of two small granite stocks. In terms of field characteristics and general geochemistry, these granites are clearly part of the Monkey Hill Intrusive Suite; the main pluton of this suite is exposed several kilometres to the west of Round Pond. MacDougall (1988) defined several types of epigenetic mineralization. Vein-hosted deposits contain significant Mo, Cu, Zn, Pb, U, F and Ba, and are variably anomalous in Co, Ag, Bi, Te and W. Grades reported by Wilton *et al.* (1986) range up to 4 percent Cu, 4 percent Zn, 2 percent Mo, 0.5 percent U and 0.2 percent Pb, with locally significant Au and Ag enrichment; for further details of grades, see MacDougall (1988). One sample contained 160 ppm W, but no enrichment in Sn was observed. Individual veins range up to 100 m in length and 3 to 4 m in width, and many are flanked by extensive zones of sulphide impregnation in their host rocks. The most common host rock is a volcanic conglomerate and/or agglomerate unit of the Upper Aillik Group; the favourability of this unit may be a function of its relative permeability (MacDougall, 1988).

Massive and stockwork sulphide veins are dominated by pyrite–pyrrhotite–magnetite, with variable chalcopyrite, molybdenite and fluorite. MacDougall (1988), by use of energy-dispersive microprobe analysis also identified minor scheelite, and various Bi, Ag and Pb tellurides and sulphosalts. Spectacular quartz-molybdenite veins appear to be relatively late in the mineralizing sequence. Carbonate-hosted Pb–Zn mineralization was reported by MacDougall and Wilton (1987), and represents a newly recognized association at Round Pond. A structurally controlled carbonate breccia zone, considered to fill a small fault, contained over 7 percent Zn and 1500 ppm Pb; surrounding country rocks contain disseminated sulphides, including chalcopyrite and molybdenite, and 800 ppb Au. In addition to these major vein types, MacDougall (1988) described fluorite veins with significant U, Zn, Pb and Ag. All of the hydrothermal vein systems are characterized by distinctive skarn-type alteration assemblages containing Ca–Fe pyroxenes and garnets, fluorite, calcite and actinolite.

MacDougall and Wilton (1987) and MacDougall (1988) suggested an epigenetic–hydrothermal model in which mineralizing fluids were derived from a high-level granite stock representing a cupola on the upper surface of a larger body (parental also to other granites of the Monkey Hill Intrusive Suite ?). It was further proposed that zonation in metal associations could be linked to distance from the source granite, thus providing a metallogenic zonation similar to that seen in other 'granophile' provinces (e.g., Strong, 1988). This is shown schematically in Figure 14 (adapted from MacDougall, 1988), with proximal Mo–Cu deposition, and distal Pn–Zn–U–F.

Linear Radioactive Zones (Round Pond – Falls Lake)

MacDougall and Wilton (1988) describe a number of 'linear' (i.e., stratiform) uranium occurrences that were discovered and assessed by BRINCO in the late 1960s, and by Placer Development in the late 1970s; these are located several kilometres south of Round Pond (Figure 12). Uranium occurs as pitchblende grains, both discrete and within mafic silicates. Minor Pb, Zn, Cu and F occur in close association, and skarn-type alteration (of the type described above) is widespread. MacDougall and Wilton (1988) concluded that these showings are of epigenetic origin and share some characteristics of the Round Pond mineralization. They consider them to be a distal 'granophile' mineral association related to the same mineralizing system postulated for the Round Pond area.

Big Bight Pb–Zn–Au–Ag Vein Mineralization

Several carbonate-hosted Pb–Zn veins were discovered in 1963 near Big Bight; these cut pyritic felsic metavolcanic

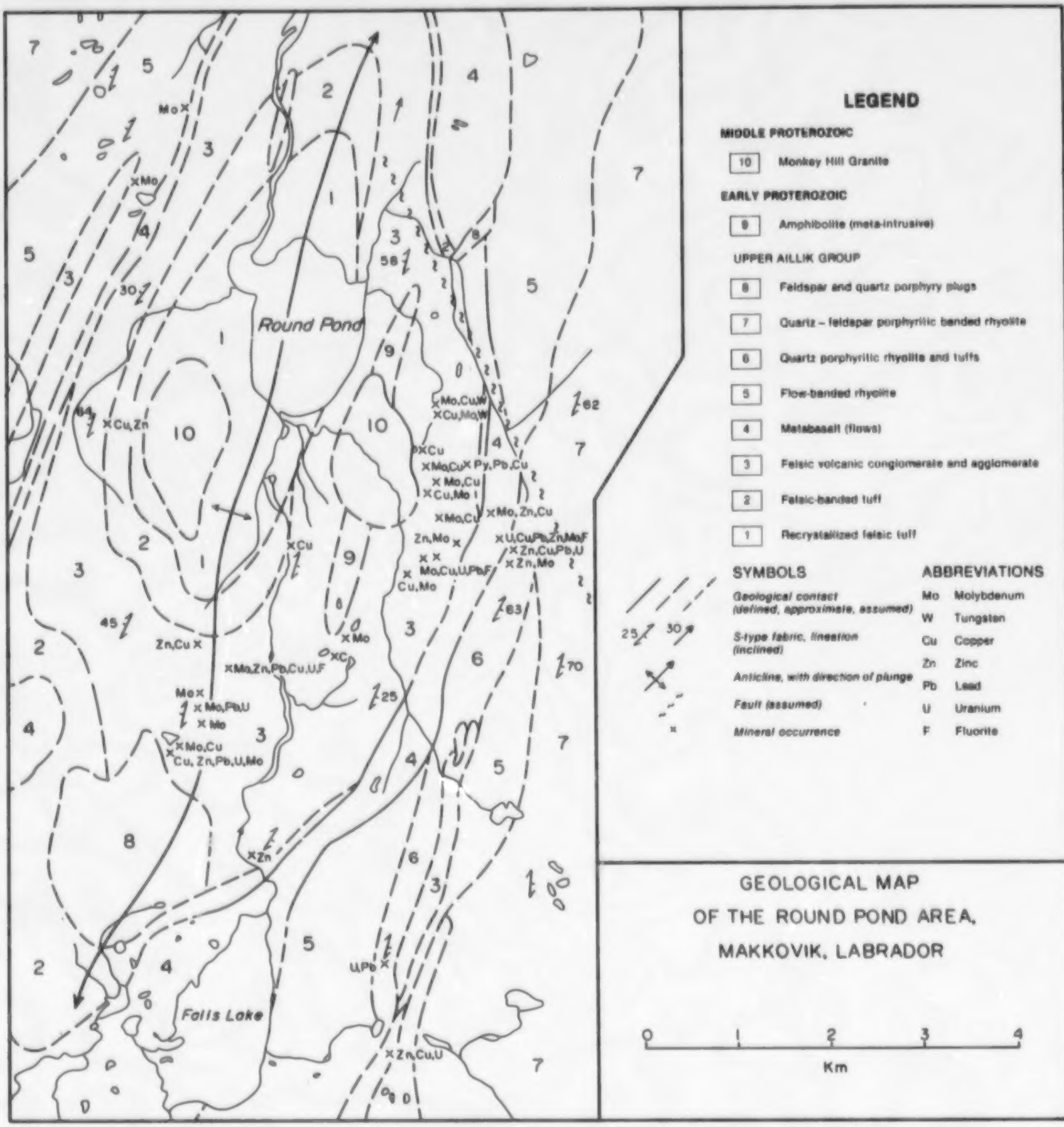


Figure 13. *Geology of the area around Round Pond, south of Makkovik, and locations of important mineral occurrences forming part of the Round Pond polymetallic vein system (from MacDougall, 1988).*

rocks of the Upper Aillik Group. Individual quartz-calcite veins are up to 1 m thick, and contain galena, sphalerite and chalcopyrite, with lesser fluorite and barite. They appear to occupy small shear zones, and show evidence of minor recrystallization (descriptions from Wilton *et al.*, 1986; and Wilton, *in press*). BRINCO reported grades of up to 11 percent Pb, 6 percent Zn, 1700 ppm Ag and 3 ppm Au over widths of about 0.5 m. Wardle and Wilton (1985) analyzed grab samples and reported values of up to 1 ppm Au and 390 ppm Ag. Wilton (*in press*) report analyses of 4600 ppm Bi and 260 ppm Sb, and anomalous levels of Ba, Mn, Mo, and Cd.

Wilton and Wardle (1987) have suggested that mineralization at Big Bight is related to fluids derived from nearby granite plutons. The veins lie less than 1 km from

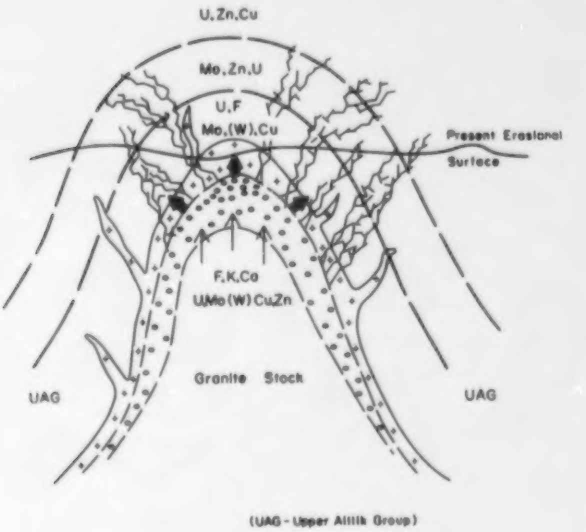


Figure 14. *Schematic illustration of the processes of mineralization envisaged by MacDougall (1988) in the Round Pond area associated with a high-level granite pluton.*

the October Harbour granite (Strawberry Intrusive Suite); the roof of the granite is exposed on the coast, and several lines of evidence suggest that Strawberry-type granite plutons are close to the surface over large areas of this peninsula. Wilton (*in press*) reports narrow (up to 12 cm wide) carbonate–quartz veins with a similar sulphide assemblage to also occur on the west side of Ford's Bight (Figure 12). In the same area, molybdenite flakes occur in fluorite-bearing pegmatites that are considered to be offshoots of the Cape Strawberry Granite.

Mo Mineralization Proximal to the Cape Strawberry Granite

MODS maps show a large number of small, disseminated Mo–Py occurrences, visible mostly as gossan zones, along both the east and west shores of Ford's Bight (Figures 11 and 12); these appear to be concentrated around the margin of the Cape Strawberry Granite. Most are very poorly documented, and there are discrepancies between locations on MODS maps and various editions of BRINCO company maps. Wardle and Wilton (1985) analyzed a number of these gossans for Ag and Au, but found little enrichment; Mo contents are variable. Wilton *et al.* (1986; Wilton, *in press*) have examined a number of these, and state that some are associated with sulphide-bearing quartz veins and/or pegmatitic veins containing minor Mo. In these respects, they resemble irregular pyritic zones observed locally within the intrusion.

The LM-12 showing is the most significant example in genetic terms. Wilton *et al.* (1986; Wilton, *in press*) describe stockwork-type fracture zones cutting recrystallized, bleached, felsic metavolcanic rocks; the veinlets contain molybdenite and pyrite, with minor sphalerite and chalcopyrite, and parts of the showing contain molybdenite-bearing pegmatite segregations. The showing lies several hundred metres south of the exposed contact of the Cape Strawberry granite, which is thought to be flat lying or gently inclined, and is about 50 to 100 m above the elevation of the exposed contact. In the area of the LM-12 showing, bleaching, alteration and pyritization of the Upper Aillik Group is widespread on a regional scale.

A similar association of stockwork mineralization, gossans and pegmatites occurs at a small showing located at the northwest corner of Wild Bight, where wall-rocks to molybdenite-bearing veins are heavily gossaned (Wilton *et al.*, 1986; Wilton and Wardle, 1987); the occurrence is close to the eastern contact of the granite.

Aillik Bay Molybdenum Deposit

This is the largest Mo occurrence in the area, with a strike length of over 2 km, and a maximum width of 25 m. It has been proved over a strike length of 750 m, to a depth of about 150 m. It was discovered in 1959. Plans for underground evaluation were prepared in the late 1960s, but this was never performed. Tonnage and grade was estimated at 2 million tonnes at 0.25 percent MoS_2, including a 30 percent dilution by barren granite and 'diorite' dykes (Gower *et al.*, 1982; based on BRINCO files). Mineralization has a regionally stratiform distribution; BRINCO geologists considered the deposit to be pretectonic, and related to a zone of shearing that they termed 'Ranger Bight Slide Zone' (King, 1963). Ryan (1977) was the first to speculate that the mineralization might be epigenetic, but Gower *et al.* (1982) accepted the evidence of a pretectonic setting presented by earlier workers.

Re-examination of the prospect by Wilton *et al.* (1986; Wilton, *in press*) suggests that, although molybdenite–pyrite veinlets are often parallel to foliation planes, they also bifurcate and coalesce in a manner reminiscent of stockwork mineralization. Fluorite and pitchblende are also reported locally. They concluded that mineralization postdated tectonism, but it remains possible that the zone of shearing was periodically reactivated. The features of the Aillik Bay prospect resemble those of low-grade Mo deposits in the Cape Strawberry area, and Wilton and Wardle (1987) suggested that it might be related to a similar granite at depth. Granite dykes and sheets, generally fine grained and locally of subvolcanic appearance, are abundant in the deposit area, but appear barren. In terms of field appearance (and limited geochemistry), these appear to resemble the Monkey Hill Intrusive Suite rather than the Strawberry Intrusive Suite.

Wilton (*in press*) cites the low Re content of the Aillik Bay molybdenite as evidence of a 'distal' setting compared to the LM-12 showing, which is Re-enriched. MacDougall (1988) refers to the presence of the molybdenite polytype 2Hi in this prospect, and at Round Pond, stating that this polytype is typical of granite-related mineralization.

Jay Lake Mo Showing

In comparison to the Kaipokok Bay–Big River area, the eastern part of the study area has received virtually no exploration attention. In 1960, BRINCO prospectors located high-grade molybdenite mineralization in a quartz vein on the shores of Jay Lake, within a narrow, east-trending, fault-bounded block of felsic metavolcanic rocks (described as quartzites at the time). Drilling encountered soil-like material beneath the vein, and the occurrence was dismissed as a glacial erratic. In 1961, five holes were drilled in the area to search for a continuation of the zone; one hole intersected minor molybdenite in an aplitic vein (MODS file 13J/9/Mo 001; summarized from BRINCO reports). The showing was reexamined during this project; although there are surface indications that the block containing the vein has moved, its large size (> 10 m diameter) and angularity (especially considering its friable and gossaned nature) suggests that it is very close to its source, and possibly simply a frost heave (F. Thompson, personal communication, 1986).

The mineralization is hosted both by vein quartz and adjacent sheared felsic metavolcanic rocks, and coats most joint faces in both rock types. On its north side, the vein is in contact with a granitoid rock with about 30 percent mafic minerals; this is not mineralized. Gower (1981) mapped this as part of his Unit 23, generally coincident with the Tukialik granite of this report, but it is more melanocratic than typical examples of this unit. Minor associated chalcopyrite, pyrrhotite and pyrite are noted in MODS files, but are not obvious on site, although the latter are presumably responsible for the widespread gossan float. Grab samples from the quartz vein contained up to 5 percent Mo (MODS data).

Features of the showing suggest an epigenetic–hydrothermal origin and a probable relationship to subjacent granite, perhaps the Tukialik granite of the Strawberry Intrusive Suite. However, as the occurrence is located within a wide zone of shearing related to the Benedict fault zone, an active Grenvillian structure, it remains possible that the Mo was mobilized at this time.

Minor Skarn-type Mineralization in the Makkovik Area

Wilton *et al.* (1986; Wilton, *in press*) have noted the common occurrence of calc-silicate (e.g., diopside–andradite–epidote–calcite) skarn-like mineral assemblages in association with a variety of mineral occurrences. They have also described several small showings where mineralization is hosted by skarns. The Tom's Cove showing (Figure 12) contains molybdenite, pyrite and chalcopyrite in a quartz–calcite–pyroxene–andradite pod, with garnets up to 5 cm in diameter. At Mink Trap Brook, near Makkovik village (Figure 12), a similar skarn, localized in an amphibolitic unit, contains galena, sphalerite and fluorite. An Ar–Ar age determination from pyroxene in the skarn gave a plateau age of 1601 ± 23 Ma. Wilton (personal communication, 1988, 1989) suspects that many small mineral occurrences hosted by amphibolitic units may be of skarn type.

Uranium Mineralization: Northeast Upper Aillik Group

Wilton *et al.* (1986; Wilton, *in press*) present a considerable volume of data on uranium mineralization in the Upper Aillik Group, and suggest that several different types occur. Specifically, they suggest that a number of showings in the northeastern part of the group are related to posttectonic granites, rather than to processes affiliated with extrusion of the Upper Aillik Group, as previously suggested by Gower *et al.* (1982).

These showings consist of uraninite, forming veinlets and fracture fillings, intergrown with fluorite, molybdenite, pyrite, sphalerite and Ca–Fe minerals of 'skarnoid' association. Strong hematization forms a characteristic alteration signature. Examples cited by Wilton (*in press*) include the Sunil, A-7, John Michelin and #5 showings (Figure 12). Wilton and Wardle (1987) cite the similarity of REE patterns in altered rocks from Pb–Zn, Mo and U mineralization in this area as evidence of a common genetic link to posttectonic granites.

A showing termed the 7-11 showing (actually composed of two virtually coincident zones, originally termed #7 and #11), near Winter Lake (Figure 12), received special mention by Wilton (*in press*), as U mineralization is associated with anomalous Ag (up to 27 ppm). Mineralization at this locality consists of carbonate-bearing veinlets crosscutting the felsic metavolcanic host rocks. BRINCO geologists reported the presence of Stromeyerite, a complex Ag–Cu sulphosalt, and Ag assays of over 800 ounces/ton; Wilton (*in press*) were unable to reproduce this amazing assay. This showing, and a number of small U occurrences in the Bernard Lake–Winter Lake area (Figures 11 and 12) are spatially (and possibly genetically) associated with the the Pistol Lake granite (Lanceground Intrusive Suite). As discussed subsequently, these granites have geochemical features suggestive of specialization.

Uranium Mineralization: Southwest Upper Aillik Group

As noted by Wilton and Wardle (1987) and alluded to by Gower *et al.* (1982), there are differences in the styles of mineralization exhibited by northeastern and southwestern portions of the Upper Aillik Group, that are manifested partly in the polymetallic signature of the former. In the case of uranium mineralization, Wilton and Wardle (1987) and Wilton (personal communication, 1988, 1989) suggest that the major type of uranium mineralization in the southwestern portion, including the important Michelin deposit, is related to (broadly) synvolcanic processes associated with formation of the Upper Aillik Group. For these deposits, the model proposed by Gower *et al.* (1982), involving leaching of U by hydrothermal solutions percolating through the volcanic pile,

is considered valid in general terms. They cite the similarity of REE patterns between mineralization and host volcanic rocks (proximal and distal) as evidence of a genetic link; in the northeastern area, REE patterns in altered rocks are distinct from those of host metavolcanic rocks (Wilton *in press*, and personal communication, 1989).

Uranium, and lesser Pb–Zn–Cu mineralization in the Burnt Lake–Emben area (Figure 12) may, however, partly be related to nearby posttectonic granites, according to MacKenzie and Wilton (1987) and MacKenzie (1991). In this area, it is postulated that a later phase of epigenetic base metal mineralization has been superimposed upon (and has locally remobilized) somewhat older U mineralization. MacKenzie (1991) relates this episode to the nearby fine-grained granite at Burnt Lake, which, as noted above, contains disseminated Mo near its contact.

Speculations Concerning Mineralization in the Upper and (Possibly) Lower Aillik Groups

As part of the regional report for the Kaipokok Bay–Big River area (Gower *et al.*, 1982), the present author proposed an integrated model for U ($\pm$ Mo) mineralization in both portions of the Aillik Group. Wilton *et al.* (1986; Wilton, *in press*) have shown that much of the mineralization in the northeastern part of the Upper Aillik Group is of epigenetic affinity, and probably linked to posttectonic granites. However, they suggest that the previous 'synvolcanic' model remains valid in the southwestern zone of the Upper Aillik Group, and perhaps also in the Lower Aillik Group.

It is important to note that some of the differences between these two models are more semantic than real. The Upper Aillik Group is (or was) a high-silica, evolved, volcanic suite that includes subvolcanic intrusive rocks, and is a high-level manifestation of granitoid plutonism. U–Pb age data collected as part of this project (Kerr and Krogh, 1990; Kerr *et al.*, 1992) demonstrate that many posttectonic suites are similar in age to parts of the Upper Aillik Group. Foliated, high-silica, fluorite-bearing granites of the Kennedy Mountain Intrusive Suite are logical candidates for plutonic equivalents of Upper Aillik volcanic rocks. In section 5, it is shown that patterns of alkali-metasomatism, closely similar to those that characterize uranium deposits at, for example, Michelin, can be recognized in these plutonic rocks.

In summary, the Gower *et al.* (1982) model and those of Wilton *et al.* (1986; Wilton, *in press*) are by no means divergent viewpoints. To the contrary, the existence of uranium mineralization associated with 1800 Ma or older felsic volcanism may simply record the operation of an earlier episode of granite-related mineralization prior to the onset of Late Makkovikian deformation. Recrystallization, metamorphism and structural disruption associated with the Makkovikian deformation may have obscured original relationships to syntectonic Makkovikian granitoid rocks.

SUMMARY AND DISCUSSION

Although the Central Mineral Belt has yet to yield a producing mine, it represents one of the most promising areas in Labrador from an exploration viewpoint. In the eastern part of the belt, a wide range of deposit types and commodities occur, ranging from syngenetic massive sulphides of the Moran Lake Group (North and Wilton, 1988) to the clearly epigenetic, vein-style deposits at Round Pond and Big Bight (MacDougall, 1988; Wilton, *in press*). Although the genesis of many smaller occurrences remains uncertain, the work of Derek Wilton and others suggests very strongly that mineralization in the Upper Aillik Group is, in a broad sense, linked to felsic magmatism. In the northeastern portion of the area, the posttectonic, epigenetic, styles of mineralization are indicative of a link to posttectonic magmatism; the subtly different uranium mineralization in the southwestern portion of the area may instead be linked to the earlier felsic magmatism represented by the Upper Aillik Group and possibly some foliated granites.

Links Between Mineralization and Specific Granitoid Associations

The most obvious examples of links between granite plutons and concentrations of mineral occurrences lie in the area south and east of Makkovik. The Monkey Hill Intrusive Suite contains both endocontact and exocontact Mo mineralization associated with small stocks or cupolas; distal associations of Pb–Zn and U–F are observed at Round Pond, where the spatial relationship between mineralization and granite plugs is very clear. Geochemical data from the Round Pond granites (see MacDougall, 1988) suggests that their compositions have been affected by hydrothermal processes. These observations implicate high-level granites of the Labradorian (ca. 1640 Ma) Monkey Hill Intrusive Suite in polymetallic mineralization. The compositionally similar Burnt Lake granite in the southwest contains similar endocontact Mo and, according to MacKenzie (1991) may be responsible for a phase of minor base-metal mineralization at Burnt Lake. In both cases, there appears to be a similar zonation, from proximal Mo to distal Pb–Zn–F ($\pm$ U) mineralization.

There also appears to be a good case for a genetic link between the Cape Strawberry granite and a number of nearby mineral occurrences (Wilton and Wardle, 1987; Kerr, 1987; 1988). Endocontact mineralization is mostly absent, except for disseminated fluorite and pyrite, but Mo occurs in associated fluorite-bearing pegmatites. The spatial association with Mo-bearing gossanous zones, including the stockwork-type mineralization at the LM-12 showing, is marked. The Pb–Zn vein mineralization at Big Bight may be a more distal manifestation of the mineralizing system, as observed at Round Pond, but there are no granitic pegmatites exposed at the showing itself. Ryan (1977) and Wilton and Wardle (1987) speculated on an association between the Aillik Bay Mo deposit and an unseen offshoot of this granite, but this is difficult to verify; posttectonic granites of the Monkey Hill Intrusive Suite are also within a few kilometres of the locality.

Additional evidence for mineral potential is present in the form of Cu–Pb mineralization associated with aplitic zones in the related Dog Islands granite.

The Lanceground Intrusive Suite, so far as is known, hosts no endocontact mineralization, with the exception of disseminated fluorite and strongly anomalous Zr in a possibly related dyke. There is a possible spatial relationship to scattered U occurrences, locally with Ag, in the Winter Lake–Bernard Lake area.

Possible Multiple Mineralization Events Related to Magmatic Pulses

As mentioned above, possible 'synvolcanic' uranium deposits in the Upper Aillik also represent mineralization linked to felsic (i.e., granitoid) magmatism, presumably of 1800 Ma or older age. There is also good evidence of granite-related mineralization associated with granitoid suites of ca. 1720 Ma age (Cape Strawberry granite) and ca. 1640 Ma age (Monkey Hill Intrusive Suite); the latter two events clearly overlap in space in the area around Makkovik.

Collectively, these observations imply that there are at least three discrete episodes where granitoid magmatism led to the development of mineralizing systems. This may be highly significant, in that a number of workers have remarked upon the 'cumulative' nature of granophile, and particularly Sn mineralization (see Strong, 1988 for review). Many areas of Sn mineralization (e.g., Bolivia, Nigeria, southern Africa) have several periods of granite-related mineralization, commencing with pegmatite-hosted mineralization in basement rocks, and culminating in mineralization associated with young high-level granites. It has been suggested that progressive concentration of ore metals by repeated magmatism is a factor in this type of association. It must, however, be pointed out that some well-known granophile provinces (e.g., Cornwall, Malaysia) show no such association.

DESCRIPTIVE GEOCHEMISTRY

INTRODUCTION

Discussion of geochemical data collected during this project is presented in two sections. This section deals with the geochemical characteristics of the discrete plutonic associations described in the preceding section, and of individual units within these groupings. The emphasis here is descriptive rather than interpretative or comparative. The following section examines the geochemical data from a comparative perspective, and examines contrasts between, and discrimination of, suites, assesses their characteristics with reference to other specialized granite suites, and discusses their geochemical affinities and possible tectonic settings. Spatial geochemical variation patterns are dealt with in the appendices.

Sample Populations

Lithogeochemical surveys during this project were structured, and the samples fell into three broad groups or 'sample populations'.

1. 'Regional samples' were collected at approximately 2 km intervals using a regular grid and preselected sample sites. These provide an unbiased view of the abundance and distribution of different rock types within the area; for example, this population is representative of the areal proportions of rock types.

2. 'Follow-up samples' were collected from localized areas defined by results from regional sampling. Sample sites were preselected at approximately 1 km intervals. These are intended to evaluate patterns within favourable units by increasing sampling density.

3. 'Geological samples' were collected on a routine basis during mapping. These have no predetermined sampling pattern and mostly represent typical examples of different geological units. A few of these samples represent unusual or aberrant rock types (e.g., mineralized or altered samples). This population is biased slightly toward coastal areas (where the best and most easily accessible areas are located), but is close to compositionally representative, as it covers all units.

Assessment of frequency spectra and univariate statistics indicates that the characteristics of the regional population are essentially unaffected by inclusion of the geological population, and the two have been combined for most discussions of regional patterns. However, the follow-up population is strongly biased toward high-SiO_2 granitic compositions, because it was intended to provide more information on specialized units; hence it is excluded from such discussions. Discussion of individual units is based on data from all sources.

Sample populations are distinguished by different numbering systems. Regional samples have 7-digit numbers commencing with 0241 or 0242; follow-up sample numbers commence with 0248 and geological sample numbers commence with 0249.

Sampling Methods and Sample Processing

Sampling methodology for both regional and follow-up surveys follows methods commonly employed in geochemical exploration surveys (e.g., Garrett, 1983). It is based loosely on methods employed during a similar mapping and sampling project in southeastern Newfoundland (Dickson, 1983).

Areas underlain by granitoid rocks were first divided into a number of 2 by 2-km-grid cells using the UTM grid superimposed on all National Topographic System (NTS) topographic maps. Each cell was then further subdivided into 16 smaller cells measuring 0.5 by 0.5 km. One of these cells was then selected on a random basis for the sample site. Where grid cells straddled a contact between different units, one sample site was selected on each side of the contact.

In the field, the first point examined from the air was located at the centre of the chosen 0.5 by 0.5 km cell; the rock sample was collected as close as possible to this location. Search for outcrop was conducted in an outward pattern from the preselected location until a suitable site was located. In practical terms, the final determinant of sample location usually became the presence of a topographic marker such as a small pond, river channel or swamp, or (in wooded areas) the presence of a landing spot. Strenuous efforts were taken to avoid sampling prominent topographic highs such as hilltops unless they were specifically preselected. In areas of relatively good exposure, this method worked effectively; it was less effective in poorly exposed zones, where often only one outcrop was present in a given 2 by 2-km-grid cell, and many grid cells lacked complete exposure. In these areas, the original grid pattern was adhered to for spacing control, but sampling cannot strictly be regarded as random.

Rock samples consisted of 4 to 8 kg of fresh material; a special effort was made to collect large samples of coarse grained or strongly porphyritic rock types. Outcrop duplicates were collected on a routine basis (approximately 1 in 20 samples) from sites separated by 1 to 5 m. In cases where outcrops contained more than one phase, two or more samples were collected, and estimates made of the relative abundance of different components. Weathered material was mostly removed on the outcrop to minimize contamination. Final cleaning and rejection of unsuitable material with veins and xenoliths was carried out at base camp. In most cases, the sample was reduced on the outcrop to a size (<5 cm maximum dimension) suitable for direct processing in the jaw crusher. A 0.5 to 1 kg sample was retained for slabbing and staining, and a small chunk retained for thin sectioning. All samples were coded using a numeric coding form to record co-ordinates and describe physical features such as colour, grain size, texture and visible mineralogy. All samples were processed with a jaw crusher, split repeatedly to produce a representative aliquot, and then powdered using a ceramic ring bowl mill to avoid contamination by tungsten carbide.

Laboratory Procedures

Laboratory procedures at the Department of Natural Resources laboratory are described in detail by Wagenbauer *et al.* (1983). About 0.1 g of sample was fused with lithium metaborate and taken into solution via HCl−HF digestion for major element and Zr analysis. About 1 g of sample was taken into solution via a $HF-HCl-HClO_4$ digestion for trace-element analysis (excluding Zr and F). About 0.25 g of sample was fused with $Na_2CO_3-KNO_3$ flux, and taken into solution with citric acid for fluorine analysis. Loss on ignition (LOI) was determined after heating a portion of the sample powder to 1000° C in a muffle furnace. Separate aliquots of sample powder were weighed and sent out for external analysis of selected trace elements.

Analytical Methods

Major elements were determined by atomic-absorption spectrophotometry (AAS), using standard solutions supplied by CANLAB Limited. Ferrous iron was determined by addition of vanadium, followed by titration using standard potassium dichromate solutions. Li, V, Cr, Ni, Cu, Zn, Rb, Sr, Ba and Pb were also determined by AAS, as described above. Details of all procedures are supplied by Wagenbauer *et al.* (1983).

Ga, Y, Zr, Nb, La, Ce and Th were determined by inductively-coupled plasma emission spectroscopy (ICP-ES) using an ARL 3520 sequential spectrometer, using standard solutions supplied by SPEX Industries Limited. Note that Zr was analyzed on solutions from the major element fusion, to eliminate problems encountered with incomplete dissolution of zircon. Zr data previously reported from this project (excluding Kerr, 1989a) variably underestimates the Zr content of most samples, particularly those containing coarse-grained zircon.

Fluorine was determined via ion-selective electrode analysis (ISE) using a digital ion-analyzer, and standard solutions supplied by CANLAB Limited.

Uranium was determined externally by Nuclear Activation Services Limited, via neutron activation analysis (NAA). About 2 g of each sample was irradiated.

Sc, Cs, Sm, Yb and Hf were determined externally in selected samples by Becquerel Laboratories, using standard NAA methods. This forms part of the 'gold+33' commercial package. About 10 g of each sample was irradiated. A range of other elements determined via this method, including gold itself, are not reported here because of low and/or highly imprecise abundances, or because they duplicate data obtained by other methods.

Tin was determined in selected samples by Bondar-Clegg Incorporated, via wavelength-dispersive X-Ray fluorescence (XRF) analysis, on a pellet containing about 5 g of sample.

Control and Assessment of Analytical Program

Precision

Precision of analysis was assessed using blind duplicates. At the Department of Natural Resources laboratory, 1 analysis in 20 was a duplicate, split prior to grinding. 'Precision' is defined as:

$$\text{PRECISION } (\pm\ \%) = 100 \times \frac{\text{absolute value } (V_1 - V_2)}{\text{mean value of } (V_1,\ V_2)}$$

(where V_1 and V_2 are the duplicate determinations of a sample).

At low abundance levels, precision is worse (i.e., ± a higher percentage) than at high values. Mean precision is thus strongly influenced by outlying values at or near detection limits, and the median (50th percentile) value is preferred here as an assessment of 'average' precision in analysis.

Table 2 lists precision data for all elements reported here. For elements with generally low abundances (e.g., V), poor mean precision results from many determinations at or near detection limit; note the large differences between mean and median precision for Cr, Ni and Mo, which reflects their near-detection-limit values in many samples. In the case of Sn, data are capable only of resolving anomalous samples. Apparent poor precision for Th is mostly induced by mafic rocks containing only 1 to 2 ppm Th; if these are excluded, precision is closer to ± 6 percent.

Detection Limits

Detection limits quoted for the Department of Natural Resources laboratory are concentration values at which precision is approximately ± 100 percent. These are based on blind duplicates measured over several years from all rock types (Wagenbauer *et al.*, 1983; Wagenbauer, 1988).

Table 2 lists detection limits. The value for Sn (1 ppm) is that quoted by the analyst; all others are based on multiple determinations over several years. Detection limits for Sc, Cs, Sm, Yb and Hf are based on a survey by P.H. Davenport (personal communication, 1988) using lake sediment samples, and are generally higher than limits quoted by the analyst.

Accuracy

At the Department of Natural Resources laboratory, 1 sample in 20 is either an internal or international standard. Repeated determinations conducted during this project were compared with recommended values quoted by Abbey (1979, 1983). Recommended values for internal standards are based on measurements over several years by different methods.

Table 3 lists mean analyses and standard deviations for the international standards MRG-1, SY-2 and GSP-1, compared to the recommended values listed by Abbey (1979, 1983). There is good agreement for most elements. Notable exceptions include Ni and Ce, which are somewhat lower than recommended values for MRG-1 and SY-2 respectively. However, in the case of Ce, ICP-ES data for SY-2 are in close agreement with ICP-MS data from Memorial University of Newfoundland (Kerr, 1989a), suggesting that the accepted value may be unreasonably high.

Accuracy for U and F was monitored only by internal Department of Natural Resources standards. Data for these are in good agreement with compilations of previous results and are within their respective precision envelopes.

SYNTECTONIC MAKKOVIKIAN PLUTONIC ROCKS

Syntectonic Makkovikian plutonic rocks are represented by 186 samples; 121 of these are from 'regional' samples collected on a 2-km-grid spacing. The remainder are follow-up samples (mostly from the Kennedy Mountain Intrusive Suite), and a small number of geological samples from all units. Samples were not collected from the Island Harbour Bay intrusive suite; this is represented by 20 unpublished analyses supplied by B. Ryan (personal communication, 1987). Data (major elements only) from this suite were also supplied by I. Ermanovics (personal communication, 1988); these have not been utilized in this study.

General Geochemistry

Summary of Numerical Data

Average major, trace and partial CIPW normative compositions of syntectonic Makkovikian plutonic units are listed in Table 4. The Long Island Quartz Monzonite and tonalite to granodiorite of the Island Harbour Bay intrusive suite are silica-poor (63 to 65 percent SiO_2) compared to all other units (72 to 75 percent SiO_2). The four component units of the Kennedy Mountain Intrusive Suite have similar major- and trace-element compositions, as do the two geographic subdivisions of the Long Island Quartz Monzonite. The Melody Granite is similar in composition to granites of the Kennedy Mountain Intrusive Suite.

The remaining units show similar major-element compositions but distinct trace-element patterns. The Pitre Lake granite is characterized by high Rb, F and Li relative to all other units. The Manak Island and Brumwater units are similar, but the former shows higher Ba and Sr, consistent with a lower SiO_2 content. These units, and the granites from the Island Harbour Bay intrusive suite, are distinguished by low Zr, Y, Nb, La and Ce compared to the Long Island and Kennedy Mountain units. The mean composition for the Deus Cape granodiorite (2 samples only) is probably not representative of the unit, which covers a large geographic area (Gower, 1981).

Abundance and Distribution of Rock Types

IUGS rock types were calculated from normative data (using Barth mesonorms, rather than the CIPW normative data listed in Table 4), using the empirical classification method of Streckeisen and LeMaitre (1979). This was restricted to regional and geological sample populations, and thus provides an unbiased method of describing compositional spectra. Relative abundances (Figure 15) indicate that syntectonic Makkovikian plutonic rocks are dominated by granite (*ss*) and alkali-feldspar granite, with lesser amounts of quartz monzonite, quartz syenite and monzogranite.

The Long Island unit contains most of the quartz monzonite to monzogranite, whereas the Kennedy Mountain

Table 2. Abundance levels, detection limits and estimates of precision for major and trace elements determined at, or via, the Department of Natural Resources laboratory

Variable	Lab.	Analytical Method	Detection Limit	Mean Value	Range	Number of Analyses	Number of Duplicates	Precision (± %) Mean	Precision (± %) Median
Oxide (wt%)									
SiO_2	NDNR	AAS	0.07	67.42	39.25–88.45	1489	73	0.57	0.38
TiO_2	NDNR	AAS	0.01	0.48	0.01– 2.77	1489	73	8.37	4.35
Al_2O_3	NDNR	AAS	0.01	14.53	4.60–25.40	1489	73	1.06	0.87
Fe_2O_3	NDNR	AAS	0.01	1.45	0.00–27.39	1489	73	10.39	6.54
FeO	NDNR	Titration	0.01	2.32	0.01–14.04	1481	73	9.16	3.96
MnO	NDNR	AAS	0.01	0.08	0.01– 0.45	1489	73	5.92	0.00
MgO	NDNR	AAS	0.01	1.35	0.01–28.02	1489	73	9.69	2.30
CaO	NDNR	AAS	0.01	2.44	0.01–16.20	1489	73	4.17	1.46
Na_2O	NDNR	AAS	0.01	4.10	0.15–10.90	1489	73	1.45	0.79
K_2O	NDNR	AAS	0.01	4.52	0.06–12.06	1489	73	4.22	1.01
P_2O_5	NDNR	AAS	0.01	0.13	0.01– 2.26	1489	73	12.86	4.65
LOI	NDNR	Oven Drying	n/a	0.71	0.02– 6.02	1485	73	13.70	7.02
Element (ppm)									
Li	NDNR	AAS	5	21.0	1–286	1491	73	13.29	8.22
F	NDNR	ISE	30	866.5	11–9968	1487	52	15.51	9.38
Sc	Becquerel	INAA	0.1	4.5	0.2–75.0	529	23	22.14	9.52
V	NDNR	AAS	20	49.7	1–705	1494	73	25.52	15.40
Cr	NDNR	AAS	1	34.3	1–1840	1491	73	20.39	5.70
Ni	NDNR	AAS	1	10.3	1–823	1491	73	18.86	0.00
Cu	NDNR	AAS	1	15.1	1–809	1491	73	7.41	0.00
Zn	NDNR	AAS	1	70.0	1–527	1491	73	3.69	2.53
Ga	NDNR	ICP-ES	1	15.9	1–71	1490	74	5.26	4.44
Rb	NDNR	AAS	5	144.5	1–1250	1491	73	6.69	2.84
Sr	NDNR	AAS	2	250.8	2–1930	1490	73	5.76	1.90
Y	NDNR	ICP-ES	1	40.9	2–381	1490	74	3.90	3.45
Zr	NDNR	ICP-ES	1	229.4	11–2880	1490	74	6.24	4.44
Nb	NDNR	ICP-ES	1	19.0	1–249	1490	74	7.00	3.64
Mo	NDNR	AAS	2	8.3	1–4752	1491	73	19.60	0.00
Sn	B-C	XRF-ES	1	4.4	1–116	529	23	73.29	66.67
Cs	Becquerel	INAA	0.5	2.42	0.5–32.0	529	23	26.41	5.97
Ba	NDNR	AAS	30	690.8	6–5140	1491	73	9.14	3.13
La	NDNR	ICP-ES	1	59.3	1–1312	1490	74	5.26	4.65
Ce	NDNR	ICP-ES	2	119.7	1–2226	1490	74	5.46	4.06
Sm	Becquerel	INAA	0.1	11.3	0.1–113.0	529	23	7.44	4.26
Yb	Becquerel	INAA	0.5	5.6	3.0–36.0	529	23	14.85	4.00
Hf	Becquerel	INAA	1.0	11.5	1.0–150.0	529	23	24.76	12.24
Pb	NDNR	AAS	2	20.1	1–2900	1491	73	6.19	5.13
Th	NDNR	ICP-ES	1	13.3	1–163	1490	74	27.85	13.33
U	N.A.S	NAA	0.2	4.5	0.1–74.7	1491	52	9.20	6.45

ANALYSTS :

NDNR	Newfoundland Department of Natural Resources, St. John's.
N.A.S	Nuclear Activation Services, Hamilton.
Becquerel	Becquerel Laboratories, Mississauga.
B-C	Bondar-Clegg and Co. Ltd., Ottawa.

ANALYTICAL METHODS :

AAS	Atomic Absorption Spectrophotometry
ICP-ES	Inductively-Coupled Plasma Emission Spectrometry
INAA	Instrumental Neutron Activation Analysis
ISE	Ion-Selective Electrode
XRF-ES	X-Ray Fluorescence Emission Spectrometry

Table 3. Mean analyses of the international standards MRG-1, SY-2 and GSP-1 by the Department of Natural Resources laboratory, compared to recommended values (Abbey, 1979, 1983).

STANDARD	SY-2			MRG-1			GSP-1		
Major elements (wt% Oxide)									
	Mean n=3	S.D.	R.V.	Mean n=3	S.D.	R.V.	Mean n=6	S.D.	R.V.
SiO_2	60.02	0.72	60.10	39.02	0.25	39.32	66.83	0.56	67.32
TiO_2	0.14	0.01	0.14	3.89	0.05	3.69	0.66	0.02	0.66
Al_2O_3	12.20	0.13	12.20	8.54	0.04	8.50	14.97	0.13	15.28
Fe_2O_3	6.36	0.07	6.28	17.81	0.30	17.82	4.27	0.06	4.3
MnO	0.32	0.01	0.32	0.18	0.00	0.17	0.05	0	0.04
MgO	2.72	0.02	2.70	13.89	0.12	13.49	0.97	0.01	0.97
CaO	8.04	0.04	7.98	14.75	0.04	14.77	1.98	0.04	2.03
Na_2O	4.29	0.05	4.34	0.71	0.00	0.71	2.79	0.03	2.81
K_2O	4.47	0.06	4.48	0.17	0.00	0.18	5.58	0.11	5.51
P_2O_5	0.43	0.03	0.43	0.06	0.00	0.06	0.27	0.03	0.28
Trace elements by AAS (ppm)									
	n=18			n=18					
Li	90.2	7.6	93.0	10.4	3.9	4			
V	61.4	10.6	52.0	539.9	19.5	520			
Cr	7.2	1.4	10.0	327.3	21.2	420			
Ni	4.6	0.9	10.0	145.3	5.5	200			
Cu	5.2	0.6	5.0	109.1	4	136			
Zn	264.3	50.3	250.0	193.4	7	185			
Rb	210.0	21.3	220.0	12.7	4	8			
Sr	274.5	8.9	275.0	260.5	14.6	260			
Mo	3.3	0.4	3.0	4.7	1.2	5.0			
Ba	460.4	31.3	460.0	83.5	16	50			
Pb	76.6	2.7	86.0	10	0	10			
Trace elements by ICP-ES (ppm)									
	n=18			n=18					
Ga	23.9	1.4	28.0	24.5	1.2	18.0			
Y	129.7	4.6	130.0	10.5	0.8	16.0			
Zr	313.8	18.9	280.0	121.3	17.3	105.0			
Nb	25.6	1.0	23.0	13.5	0.8	20.0			
La	69.4	3.0	88.0	17.5	5.7	10.0			
Ce	164.8	5.7	210.0	38.7	3.0	25.0			
Th	383.4	27.0	380.0	1.0	0.2	1.0			
Trace elements by NAA (ppm)									
	n=12			n=9					
Sc	6.0	0.5	7.0	53.8	4.1	48.0			
Cs	2.7	0.3	2.3	0.8	0.2	0.6			
Sm	8.6	2.1	15.0	4.9	0.3	5.0			
Yb	20.4	4.0	17.0	2.2	2.0	1.0			
Hf	8.3	0.8	8.0	3.8	0.5	3.0			
Other trace elements (ppm)									
Sn	4.6	2.2	4.0	1	0	3.2			

R.V. = Recommended Value (Abbey, 1979, 1983) S.D. = Standard Deviation

Table 4. Average compositions of syntectonic Makkovikian plutonic rocks, subdivided by principal units

ANALYSES	1		2		3		4		5		6	
n[1]	14		9		19		18		74		5	
n[2]	5				8		1		16		1	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	63.22	1.27	65.46	7.11	75.05	1.37	71.05	2.73	74.49	2.63	69.35	4.36
TiO_2	0.88	0.06	0.69	0.34	0.28	0.24	0.42	0.15	0.23	0.13	0.51	0.22
Al_2O_3	15.79	0.23	15.84	2.42	12.31	0.48	13.71	0.82	12.32	1.01	14.45	1.55
Fe_2O_3	1.81	0.38	1.95	1.18	1.32	0.41	1.39	0.72	1.27	0.75	1.11	0.55
FeO	3.09	0.75	1.90	0.59	0.91	0.32	1.69	0.83	1.28	1.26	2.05	0.59
MnO	0.10	0.01	0.07	0.03	0.04	0.01	0.07	0.03	0.06	0.03	0.07	0.02
MgO	1.26	0.44	0.99	0.63	0.13	0.04	0.38	0.22	0.12	0.20	0.58	0.44
CaO	2.97	0.49	2.71	1.82	0.51	0.27	1.25	0.42	0.76	0.59	1.64	0.76
Na_2O	4.28	0.26	4.28	0.31	4.61	1.16	4.30	0.92	4.34	1.13	3.99	0.43
K_2O	4.77	0.51	4.50	0.31	4.14	1.82	4.84	1.15	4.19	1.56	5.25	0.49
P_2O_5	0.26	0.03	0.25	0.20	0.03	0.01	0.09	0.04	0.03	0.04	0.11	0.07
LOI	0.63	0.24	0.72	0.34	0.36	0.13	0.42	0.19	0.47	0.23	0.41	0.03
TOTAL	99.16		99.36		99.67		99.60		99.55		99.53	
(ppm)	Trace elements											
Li	23.6	4.6	19.9	15.8	15.2	10.2	25.6	15.5	10.4	7.0	27.2	8.1
F	873.2	214.7	809.8	499.5	661.5	544.7	936.1	315.2	1092.4	982.5	1145.8	484.2
Sc	9.6	1.7			1.5	0.6	0.8	0.0	1.1	0.7	4.4	0.0
V	76.3	19.2	49.0	31.8	12.7	6.2	21.4	8.6	12.3	10.5	45.6	21.5
Cr	5.6	3.6	3.2	1.4	4.3	4.0	3.6	1.9	5.3	4.0	3.2	2.2
Ni	2.7	1.9	1.2	0.4	1.4	1.1	1.3	0.7	1.3	1.3	1.6	0.9
Cu	9.3	3.9	5.2	2.0	2.5	0.8	5.2	4.3	3.6	3.9	6.2	4.1
Zn	74.0	8.8	61.8	17.9	65.8	29.7	73.7	24.7	87.3	61.8	60.6	19.2
Ga	18.4	1.2	14.4	4.4	16.5	7.1	14.5	5.7	17.3	7.7	18	2.0
Rb	127.9	24.4	118.0	29.2	129.7	62.1	163.0	49.3	127.9	67.4	185	42.0
Sr	327.2	40.5	348.8	274.2	31.8	9.4	103.9	55.2	51.6	78.5	137.2	86.1
Y	36.5	2.0	32.3	7.0	52.5	14.2	55.1	15.5	82.8	31.3	45.8	9.4
Zr	227.9	66.6	250.1	107.2	409.5	126.5	356.7	119.6	401.4	156.2	237.6	54.2
Nb	14.1	1.1	13.2	3.7	19.9	4.1	23.9	6.4	32.0	15.1	19.6	5.0
Mo	4.3	0.5	5.4	3.2	3.4	2.3	4.4	2.1	3.4	1.5	4.6	1.1
Sn	1.0	0.0			3.5	2.0	7.0	0.0	3.4	2.9	5	0.0
Cs	1.3	1.2			0.7	0.5	0.5	0.0	0.6	0.4	0.5	0.0
Ba	1424.3	120.6	1243.6	449.1	152.6	77.4	717.6	315.9	390.0	439.9	846	390.9
La	53.6	4.9	44.9	16.4	62.8	28.4	73.1	22.7	85.0	39.1	57.2	9.7
Ce	103.0	6.2	89.3	26.9	130.9	52.7	143.1	40.3	177.2	73.2	117.2	18.8
Sm	9.2	0.8			10.5	2.0	13.0	0.0	13.7	3.8	11	0.0
Yb	2.5	0.0			4.2	2.4	10.0	0.0	8.9	3.0	7	0.0
Hf	8.0	1.2			12.8	3.5	12.0	0.0	12.2	3.5	12	0.0
Pb	15.5	3.8	18.6	4.3	17.7	6.6	24.9	4.5	18.1	11.9	22.6	2.3
Th	9.5	2.7	8.1	9.6	10.7	7.7	19.2	6.8	15.9	10.3	23.8	12.0
U	4.9	0.8	3.3	1.0	3.7	2.5	6.3	2.9	4.5	2.9	7.16	2.8
(Wt%)	CIPW norms (partial)											
Q	12.07	1.68	17.31	11.38	31.61	2.89	24.31	5.12	31.64	5.41	21.40	8.76
C	0.00	0.00	0.09	0.15	0.03	0.07	0.01	0.03	0.01	0.07	0.02	0.05
Or	28.59	3.02	26.91	1.83	24.63	10.87	28.84	6.85	24.96	9.31	31.32	3.06
Ab	36.73	2.08	35.85	1.28	39.17	9.84	36.67	7.84	36.86	9.30	34.09	3.77
An	9.97	1.50	10.61	5.54	0.66	0.47	3.82	1.88	1.84	1.97	5.98	2.69
Di	3.05	1.23	1.34	2.07	0.84	0.63	1.53	1.07	1.08	1.21	1.42	0.99
Hy	4.62	1.78	2.31	1.72	0.26	0.39	1.81	1.51	0.94	2.08	2.89	1.12
Ol	0.00	0.00	0.39	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mt	2.67	0.56	2.63	1.35	1.64	0.57	1.69	0.90	1.57	0.80	1.62	0.81
Il	1.69	0.13	1.34	0.66	0.53	0.45	0.77	0.31	0.44	0.24	0.98	0.42

KEY TO ANALYSES (KMIS–Kennedy Mountain Intrusive Suite)

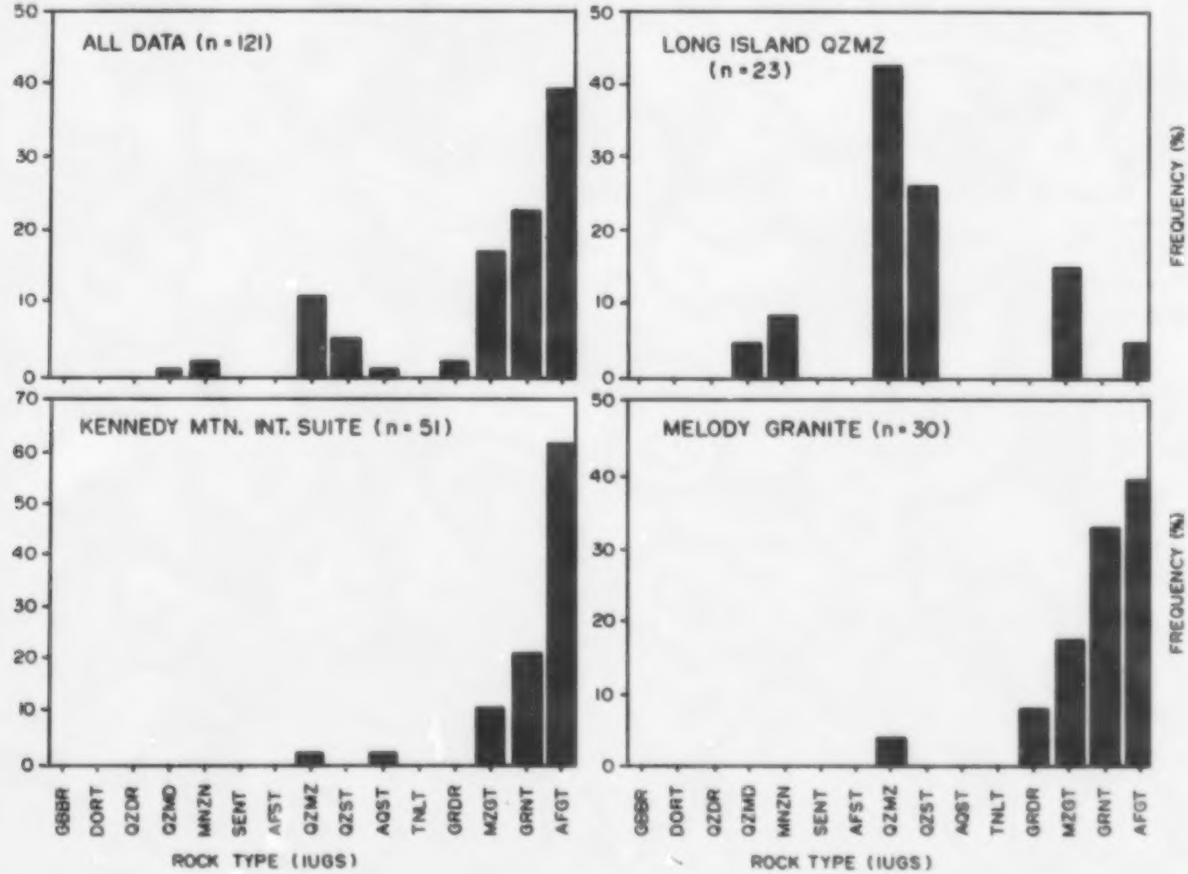
1 Long Island Quartz Monzonite (main body)
2 Kennedy Mountain granite (KMIS)
3 Cross Lake granite (KMIS)
n[1] number of analyses for all elements except those listed below.
4 Long Island Quartz Monzonite (other)
5 (KMIS) Narrows granite
6 (KMIS) other units
n[2] number of analyses for Sc, Sn, Cs, Sm, Yb and Hf.

Table 4. *(Continued)*

7		8		9		10		11		12		13	
31 19		4		4		6		2		15		5	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
72.27	3.26	72.73	1.26	76.18	0.38	70.13	0.69	75.68	4.42	66.13	6.51	73.38	1.52
0.35	0.21	0.16	0.09	0.05	0.02	0.31	0.03	0.17	0.10	0.52	0.36	0.20	0.05
13.50	1.10	14.66	0.44	12.87	0.23	15.83	0.40	12.64	1.94	16.44	1.40	14.52	0.73
0.97	0.68	0.64	0.44	0.36	0.24	1.06	0.26	1.03	0.28	1.19	0.97	0.30	0.15
1.74	1.12	0.66	0.29	0.43	0.25	0.90	0.19	0.54	0.20	2.26	1.46	0.96	0.11
0.04	0.02	0.03	0.01	0.03	0.01	0.04	0.01	0.04	0.01	0.05	0.04	0.03	0.01
0.41	0.37	0.65	0.27	0.02	0.01	0.54	0.03	0.31	0.23	1.41	1.36	0.38	0.23
1.18	0.72	0.99	0.03	0.47	0.17	1.78	0.21	0.63	0.11	3.48	1.94	0.97	0.61
3.80	0.76	5.06	0.93	4.31	0.26	4.89	0.19	3.36	1.08	4.61	0.50	4.03	0.28
4.59	0.99	3.34	1.46	4.32	0.24	3.93	0.14	4.79	0.08	2.52	1.08	4.08	1.16
0.09	0.07	0.06	0.02	0.02	0.01	0.12	0.01	0.03	0.03	0.19	0.19	0.04	0.01
0.70	0.34	0.93	0.29	0.62	0.04	0.42	0.16	0.67	0.11	0.98	0.42	0.78	0.02
99.63		99.91		99.66		99.95		99.86		99.78		99.67	
18.1	13.5	11.5	1.7	162.5	98.0	22.5	6.1	12.0	0.0				
613.7	481.2	187.5	68.4	2660.5	746.6	411.3	133.9	230.0	14.1				
2.9	1.6												
24.3	17.7	21.5	8.5	13.0	2.4	29.0	4.9	14.0	7.1	55.7	48.4	28.0	24.1
3.7	3.5	7.5	5.7	4.5	1.7	2.5	0.8	1.0	0.0	15.0	37.5	5.0	0.0
1.7	1.5	3.0	2.7	1.5	0.6	1.5	0.5	1.5	0.7				
7.3	15.1	3.5	1.3	2.0	1.2	4.5	1.2	8.5	5.0				
45.0	27.9	29.3	3.9	61.3	23.9	43.2	10.2	54.0	4.2				
18.3	2.2	6.8	1.7	16.5	7.2	13.2	2.9	16.5	2.1	21.5	2.6	19.6	3.4
122.0	36.0	96.5	41.0	411.5	163.4	79.3	24.9	164.5	37.5	70.7	24.8	257.0	166.0
106.8	89.9	273.5	47.5	7.8	2.2	596.3	75.3	48.0	25.5	540.2	290.5	173.0	177.8
45.2	17.8	5.8	1.7	125.0	32.8	8.5	1.2	41.5	21.9	10.9	7.1	45.0	51.3
361.9	162.9	88.0	38.0	114.3	23.1	162.0	26.1	256.0	53.7	163.3	76.4	110.0	19.1
20.6	5.6	2.0	0.0	36.5	11.6	5.0	1.3	23.5	0.7	8.3	5.7	20.8	18.6
3.4	1.0	2.0	0.0	2.0	0.0	2.0	0.9	3.5	0.7				
4.4	3.7												
2.2	1.4												
827.6	481.8	912.5	446.6	42.0	38.2	1560.0	174.4	209.5	171.8	774.4	330.4	674.0	592.0
85.2	38.2	13.8	4.6	12.3	4.3	26.0	5.3	49.0	2.8	29.2	11.0	22.6	5.2
171.4	66.8	19.0	11.6	32.5	9.9	46.0	8.7	103.0	5.7	50.3	17.0	36.4	8.6
13.8	5.0												
5.2	2.5												
10.8	4.1												
14.1	7.5	12.5	7.9	61.5	1.3	11.3	2.8	26.5	14.8				
12.1	6.1	1.8	1.0	23.3	18.2	4.8	2.9	20.5	7.8	6.3	4.1	24.0	19.2
3.7	2.0	1.7	0.5	8.6	8.2	1.8	0.4	5.8	2.8				
29.06	5.53	27.56	2.39	33.68	0.70	22.02	1.87	36.33	11.44	19.78	8.28	31.50	5.77
0.38	0.46	0.98	0.48	0.30	0.23	0.40	0.24	0.86	0.05	0.51	0.46	1.80	1.73
27.43	5.87	19.88	8.64	25.77	1.40	23.32	0.82	28.50	0.57	15.08	6.46	24.39	6.87
32.48	6.48	43.23	8.08	36.77	2.22	41.55	1.66	28.67	9.27	39.48	4.30	34.42	2.37
5.24	3.02	4.84	0.26	2.24	0.90	8.59	1.06	2.99	0.40	15.51	7.54	4.75	3.13
0.20	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	1.89	0.00	0.00
2.94	2.30	2.12	0.72	0.60	0.40	1.78	0.43	0.77	0.59	5.52	4.53	2.22	0.45
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.26	0.00	0.00
1.25	0.74	0.94	0.64	0.38	0.14	1.40	0.32	1.37	0.38	1.75	1.43	0.44	0.21
0.67	0.41	0.31	0.17	0.10	0.03	0.58	0.07	0.33	0.19	0.99	0.70	0.38	0.11

KEY TO ANALYSES (IHBIS–Island Harbour Bay Intrusive Suite)

7 Melody Granite
8 Brumwater granite
9 Manak Island granodiorite
10 (tonalite-granodiorite) IHBIS
11 Pitre Lake granite
12 Deus Cape granodiorite
13 (granite) IHBIS



KEY TO ROCK TYPES

GBBR–Gabbro
DORT–Diorite
QZDR–Quartz diorite
QZMD–Quartz monzodiorite
MNZN–Monzonite
SENT–Syenite
AFST–Alkali feldspar syenite
QZMZ–Quartz monzonite
QZST–Quartz Syenite
AQST–Alakali feldspar quartz syenite
TNLT–Tonalite
GRDR–Granodiorite
MZGT–Monzogranite
GRNT–Granite (ss)
AFGT–Alkali feldspar granite

Figure 15. *Relative abundance of IUGS rock types amongst syntectonic Makkovikian plutonic rocks, calculated from normative mineralogy using the method of Streckeisen and LeMaitre (1979). Note that this is based on Barth mesonorms, not the CIPW norms listed in tables. Abundances are not given for minor units, due to the small number of samples analyzed.*

Intrusive Suite and Melody Granite are dominated by granite and alkali-feldspar granite. Minor units (not shown in the figure due to small amounts of data) are also dominated by granite (*ss*), except for the Manak Island unit, which is a monzogranite. No analysis has been attempted for the Island Harbour Bay intrusive suite, as the numbers of data are insufficient, but a major-element study by I. Ermanovics (personal communication, 1988) suggests a wide range of compositions, including significant tonalite–trondhjemite (see also Ryan *et al.*, 1983 for descriptions of compositions).

Geochemical Trends and Contrasts

For the purposes of graphical representation, syntectonic Makkovikian plutonic rocks are subdivided into three groups (A, B and C) represented by separate columns of diagrams in variation diagrams (e.g. see Figure 16). This method is included to reduce 'clutter' in the diagrams and no genetic links are implied by these groupings.

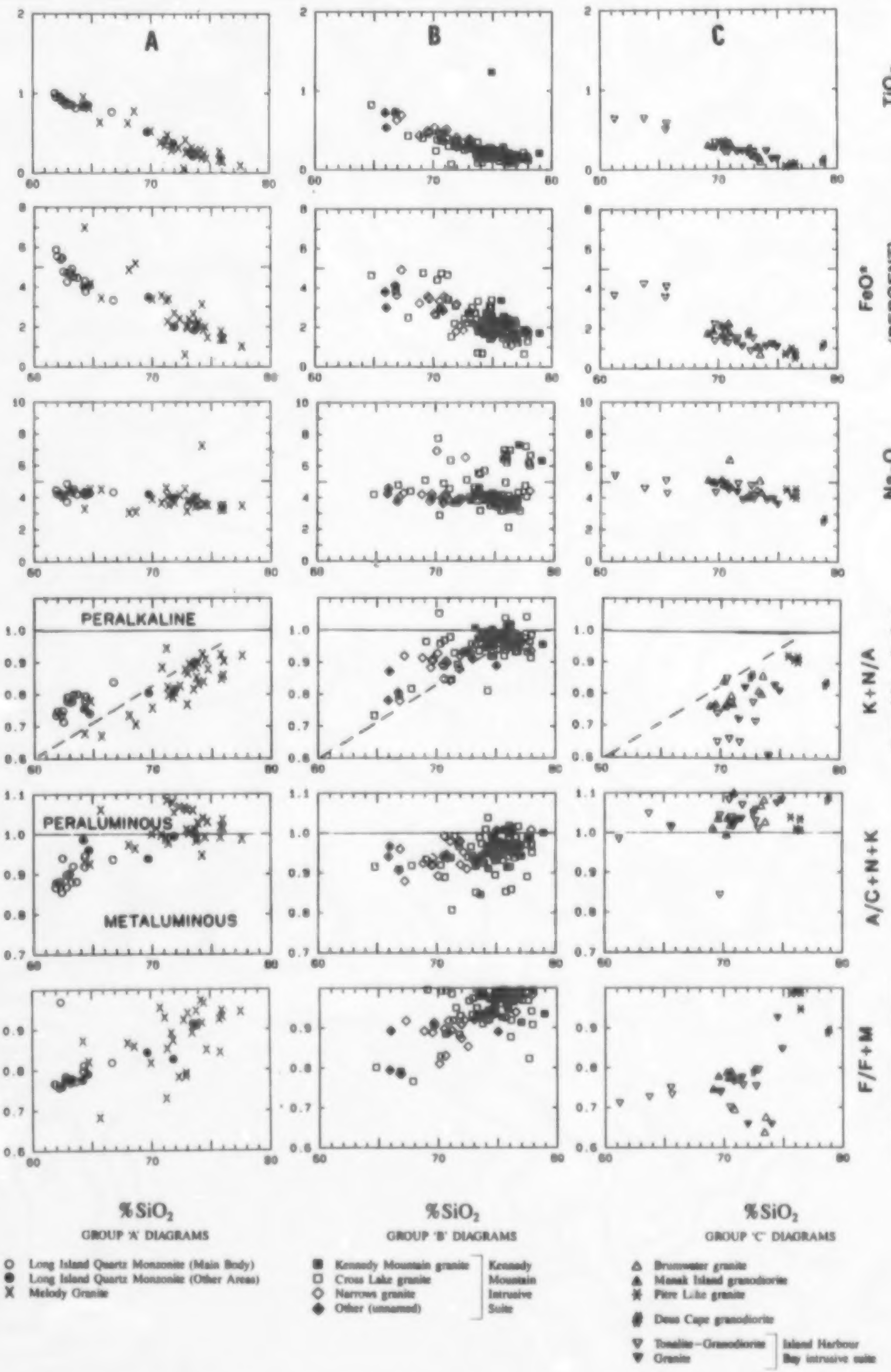


Figure 16. *Variation of selected major elements and derived ratios in syntectonic Makkovikian plutonic units.*

Major-Element Patterns

Major element variations (Figure 16) show patterns typical of virtually all igneous suites. All elements (except Na_2O and K_2O (not shown)) are negatively correlated with SiO_2 (e.g., TiO_2 and FeO^t), and do not discriminate between units. Within the Kennedy Mountain Intrusive Suite, the Kennedy Mountain and Cross Lake granites show the most evolved, high-SiO_2 compositions. The Melody Granite coincides with the Kennedy Mountain Intrusive Suite. Na_2O and K_2O (not shown) display little systematic variation and exhibit considerable scatter above 70 percent SiO_2 in the Kennedy Mountain Intrusive Suite.

Agpaitic Index [K+N/A] and Alumina Index [A/C+N+K] distributions provide better unit discrimination. K+N/A defines two subparallel trends, separated by the dotted line in Figure 16. The 'upper trend' includes the Long Island Quartz Monzonite and Kennedy Mountain Intrusive Suite, and terminates in a dense grouping at 75 to 78 percent SiO_2 that includes some peralkaline compositions (K+N/A > 1.0). The 'lower trend' is defined by the Melody, Manak Island, Brumwater and Pitre Lake units, and by parts of the Island Harbour Bay intrusive suite; this terminates at K+N/A values below 0.94. A/C+N+K values indicate that the 'lower trend' units are largely peraluminous (A/C+N+K > 1.0), whereas the 'upper trend' is metaluminous. These two contrasting groups are referred to below as the metaluminous-peralkaline and peraluminous associations respectively. F/F+M ($FeO^t/(FeO^t+MgO)$) ratios indicate that the former association shows Fe-enrichment relative to most members of the peraluminous association.

Ternary AFM [$(Na_2O+K_2O)-FeO^t-MgO$] and CNK [Na_2O-K_2O-CaO] projections (Figure 17) show a superficial 'calc-alkaline' trend for all units. However, linear regression of all data suggests that the alkali-lime index (i.e., SiO_2 value at which $Na_2O+K_2O = CaO$) is about 57 percent. Thus, in the original definition of such terms (Peacock, 1931), this association is better described as alkali-calcic. The CNK projection also indicates alkali disturbance (mostly Na-enrichment), relative to the calc-alkaline trend defined by other units, in the granites of the Kennedy Mountain Intrusive Suite.

Trace-Element Patterns

So-called 'compatible' trace elements (Figures 18 and 19), which substitute for Fe and Mg in common silicates, show strong inverse correlation with SiO_2, typified by the trend for V. Only the Long Island Quartz Monzonite has significant enrichment of such elements, consistent with its lower SiO_2 content compared to other units.

Low Field Strength (LFS) trace elements (i.e., those with large ionic radii and small charges) behave in two fashions. Ba and Sr (which substitute in feldspars) are inversely correlated with SiO_2, particularly above 70 percent SiO_2. Patterns of this type are typical in high-silica igneous suites, where feldspars are fractionated from magmas. The Manak Island and Brumwater units, and parts of the Island Harbour Bay intrusive suite, are characterized by high Ba and Sr for a given SiO_2 content, compared to other units. Extreme depletion in both these elements is shown by high-silica rocks of the Kennedy Mountain Intrusive Suite, and also by the Pitre Lake granite.

Rb and Th lack good correlation with SiO_2. Weak positive trends exist below 70 percent SiO_2, but data are scattered in high-silica granites, particularly in the Kennedy Mountain Intrusive Suite. Partial data for Cs suggest that the Melody granite is enriched relative to all other units for which data are available. The Pitre Lake granite has a high Rb content; 2 samples contain over 400 ppm Rb and are excluded from the figure. Some of the granites from the Island Harbour Bay intrusive suite have Rb and Th contents similar to those of the Pitre Lake granite.

High Field Strength (HFS) trace elements (i.e., those with smaller ionic radii and higher charges) provide distinctions between units. Zr (also Nb and Hf; not shown) are enriched in the Kennedy Mountain Intrusive Suite relative to most other units, and are disorganized above 70 percent SiO_2. The Melody granite is partly coincident with the Kennedy Mountain Intrusive Suite for these elements, but shows generally lower Zr. Most other members of the peraluminous association are depleted in Zr. The Pitre Lake granite shows an unusual combination of Nb enrichment and Zr depletion, which is also shown by some granites of the Island Harbour Bay intrusive suite. Variation patterns resemble those for Zr and Nb respectively. The Island Harbour Bay intrusive suite, Manak Island, and Brumwater units are characterized by low abundances relative to the Kennedy Mountain Intrusive Suite. The Pitre Lake granite shows Y enrichment and Ce depletion.

Li is strongly enriched in the muscovite-bearing Pitre Lake granite (two samples contain over 150 ppm Li), but is low in most other units. The Kennedy Mountain Intrusive Suite shows variable Zn and F enrichment at high SiO_2 contents, and is locally strongly F-enriched (up to 4000 ppm). Granitoids of the peraluminous association are low in F, except for the Pitre Lake Granite.

Trace-Element Variation and Alkali Disturbance in the Kennedy Mountain Intrusive Suite

As noted above, there is evidence for compositional disturbance in the Na_2O and K_2O contents of this suite. Correlation between trace element behaviour and alkali disturbance in the Kennedy Mountain Intrusive Suite was assessed by using N/N+K ratios as the X-axis variable in trace-element plots (Figure 20). For LFS trace elements (e.g., Rb, U, Ba and Sr), and possibly also Li, disturbed Na-rich compositions show depletion, but there is little systematic variation of HFS elements, REE, Zn and F. This indicates that any metasomatic processes affected feldspars and micas, and had minimal effect on accessory or mafic phases where the latter reside. In conjunction with the relatively constant total alkali contents, it suggests cation-exchange as a possible

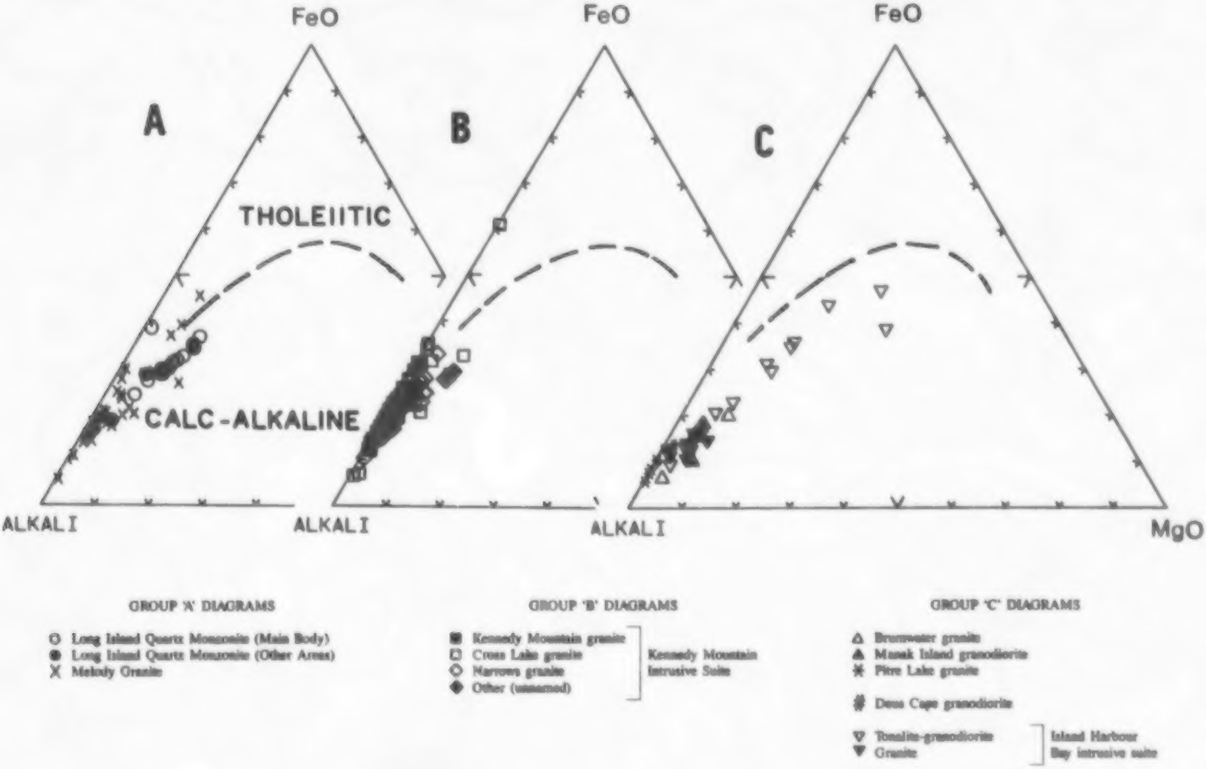


Figure 17. *AFM and CNK ternary projections for syntectonic Makkovikian plutonic units.*

mechanism (cf. White and Martin, 1980). It also indicates that the enhanced levels of fluorine, HFS elements and REE that characterize the Kennedy Mountain Intrusive Suite are primary features of the parent magmas, not a consequence of hydrothermal activity.

POSTTECTONIC MAKKOVIKIAN PLUTONIC ROCKS

Posttectonic Makkovikian plutonic rocks are represented by 460 samples; 264 of these are regional samples collected on a 2-km-random-grid spacing. The remainder include 114 follow-up samples, collected mostly from granites of the Strawberry and Lanceground Intrusive suites, and 82 geological samples distributed approximately equally amongst all units. Characteristics of and usage of sample populations have been previously explained.

It should be noted that the Freshsteak and Noarse Lake granitoids, which were included above in this association, are not discussed in this section. They are instead described briefly under 'unclassified plutonic rocks', because the geochronological data that confirms them as of Makkovikian age were not available during preparation of the geochemical variation diagrams used in the geochemical variation diagrams used in this report.

General Geochemistry

Summary of Numerical Data

Average major-element, trace-element and partial CIPW normative compositions of posttectonic Makkovikian units are listed in Table 5. The Numok Intrusive Suite is characterized by lower SiO_2 (60 to 65 percent) than other units, and is discussed separately from the remaining units, which are referred to below collectively as 'siliceous granitoids'.

Numok Intrusive Suite

The plagiophyric monzodiorite and monzonite unit has the least differentiated composition in the suite. There are significant compositional differences between the quartz monzonite unit in northern and southern zones; in the south it has lower SiO_2, and is closer in composition to the plagiophyric monzonite unit than to the syenite unit. In contrast, the quartz monzonite and quartz syenite units of the northern zone are similar in composition, although the latter is slightly richer in K_2. Trace-element patterns are also similar, except for lower F, Sr and Ba in the syenite unit. This similarity is consistent with the apparently gradational contacts between these units in the northern zone.

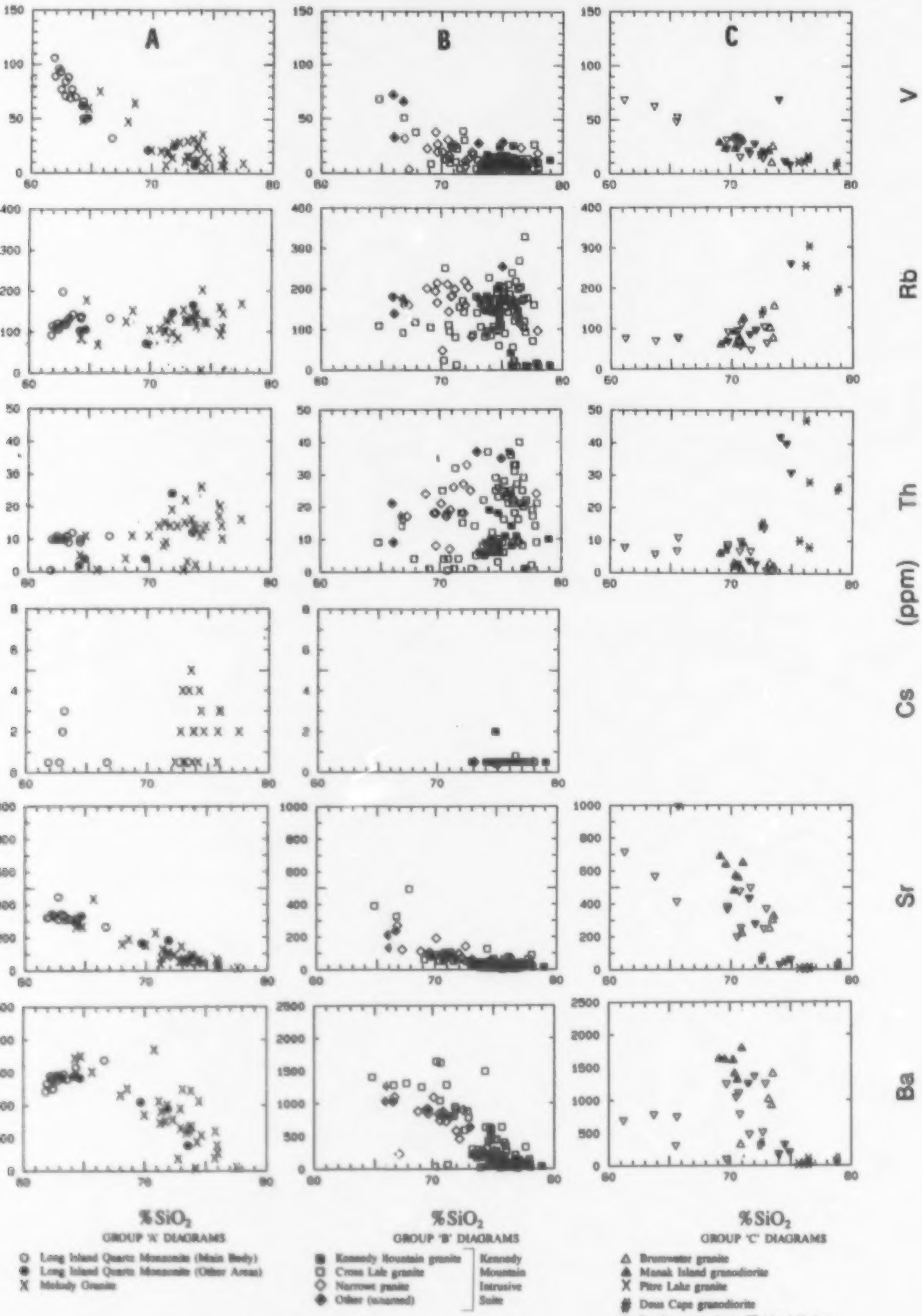


Figure 18. *V, Rb, Th, Cs, Sr and Ba vs SiO_2 in syntectonic Makkovikian plutonic units.*

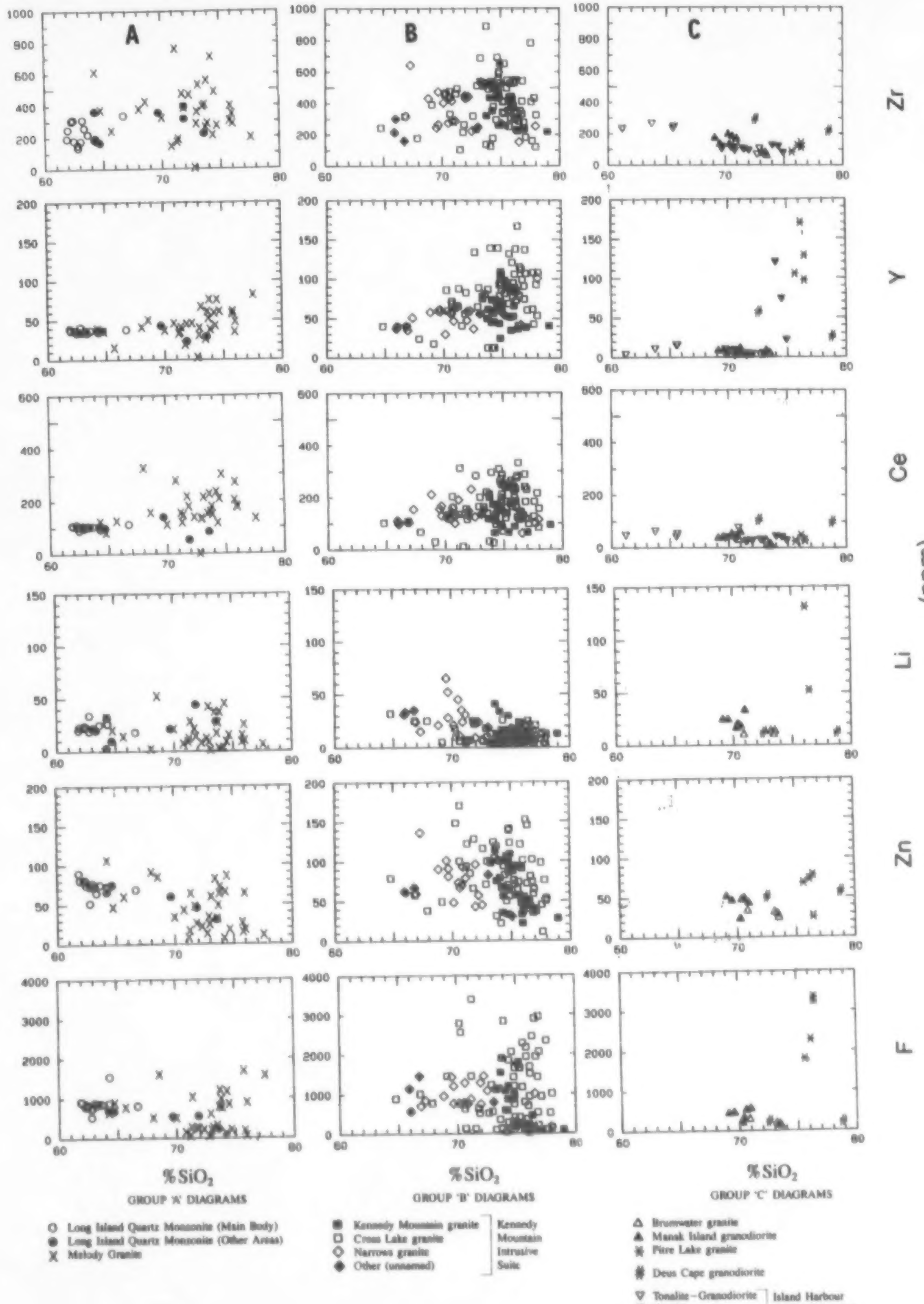


Figure 19. *Zr, Y, Ce, Li, Zn and F vs SiO_2 in syntectonic Makkovikian plutonic units.*

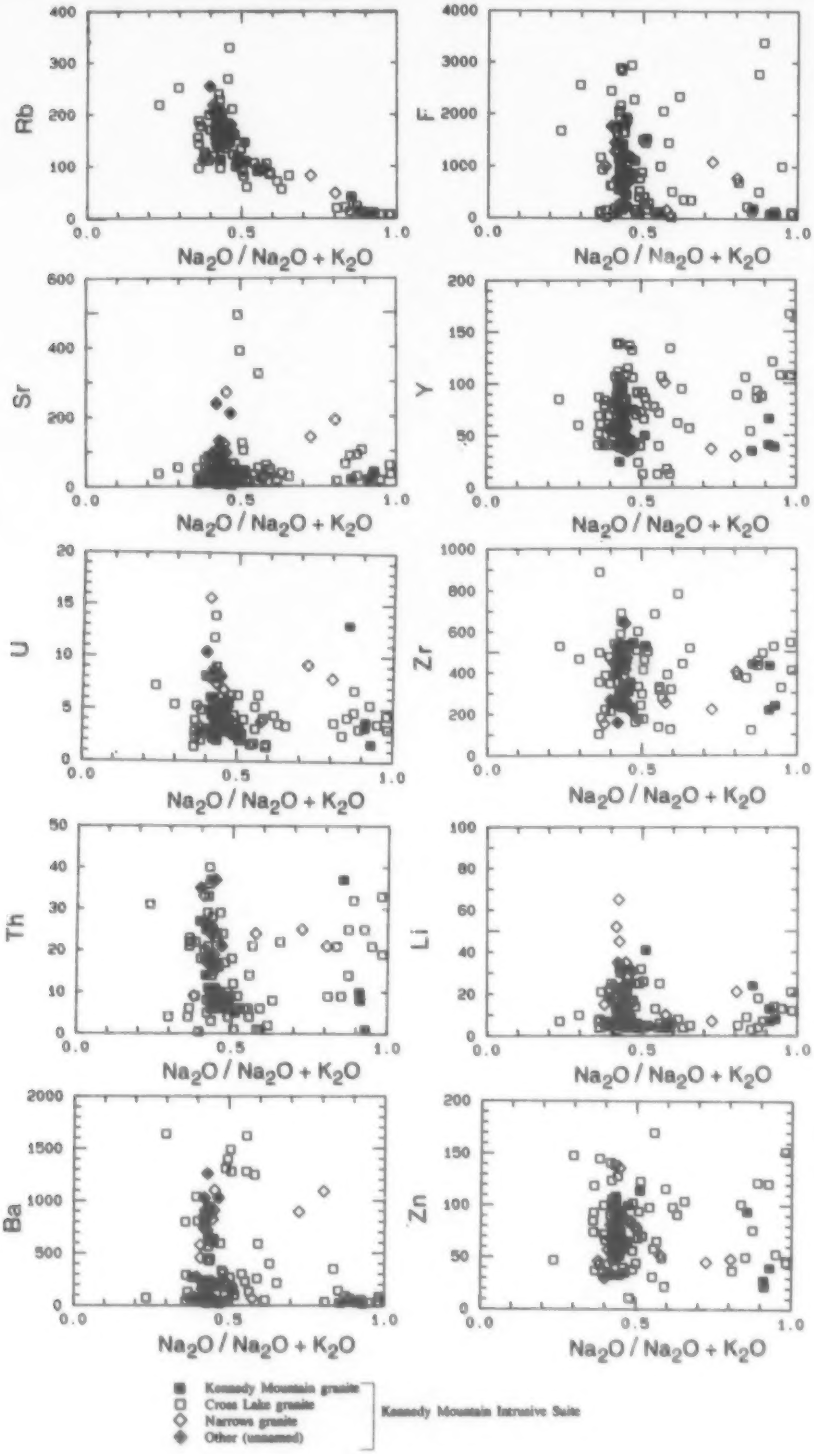


Figure 20. *Variation of selected trace elements against N/N+K [Na_2O / (Na_2O+K_2O)] in the Kennedy Mountain Intrusive Suite.*

Siliceous Granitoid Units

Contrasts in geochemistry amongst these units are subtle. The Lanceground Intrusive Suite has slightly higher mean K_2O, and lower mean Al_2O_3 and MgO than other granitoid units. The Bayhead granite has the least evolved and most variable major element composition in the Strawberry Intrusive Suite; the Cape Strawberry and Poodle Pond granites have the most evolved compositions. In the Lanceground Intrusive Suite, the Pistol Lake granite has the least evolved composition.

Trace-element patterns in the Strawberry and Lanceground Intrusive suites are generally similar, but there are small but consistent differences between them. Fluorine contents tend to be higher in the Strawberry Intrusive Suite, as do Li, Sr and Ba. The Lanceground Intrusive Suite shows generally higher levels of Zr, Y and REE. Note that the high Pb content of the Dog Islands granite is a reflection of a single anomalous sample; if this is excluded, it is similar to other members of the suite.

The Big River Granite is similar to all of the above in major element compostion, but has higher Ba and Sr, and lower F, Zn, Rb, Nb, La, Ce, Th and Y contents. Trace-element abundances in the main phase of the Big River Granite are similar to those of the Numok Intrusive Suite although the latter has a much less evolved major element composition. The equigranular phase of the Big River Granite is more siliceous than the main phase, and has lower Ba and Sr, but shows similar levels for most other trace elements.

Abundance and Distribution of Rock Types

Relative abundances of IUGS rock types calculated from normative data (regional and geological samples only, using the

methods of Streckeisen and LeMaitre, 1979) show that posttectonic Makkovikian rocks are dominated by alkali-feldspar granite and granite, with lesser quartz monzonite and quartz syenite (Figure 21). The general distribution of rock types resembles that of their syntectonic counterparts. The Numok Intrusive Suite is dominated by quartz monzonite, quartz syenite and alkali-feldspar quartz syenite. Siliceous granitoid units are dominated by alkali-feldspar granite and lesser granite (*ss*). Alkali-feldspar granite is most abundant in the Lanceground Intrusive Suite (about 80 percent of total). Within the Strawberry Intrusive Suite, only the Bayhead granite is dominated by granite (*ss*); all other units are dominated by alkali-feldspar granite (up to 60 percent of total).

Geochemical Trends and Contrasts

Posttectonic Makkovikian plutonic rocks are divided into three groups (A, B and C), represented by separate columns of variation diagrams in figures that apply to this section (e.g. see Figure 22). These subdivisions are intended primarily to reduce 'clutter' in the diagrams and do not necessarily imply genetic links between units. Note that variation diagrams using SiO_2 as the X-axis employ a different horizontal scale for the Numok Intrusive Suite, as it has a greater SiO_2 range. Y-axis scales are constant for all figure groups.

Major-Element Patterns

Major-element trends (Figures 22 and 23) against SiO_2 show expected patterns typical of all igneous suites, and do not discriminate between units well. The Numok Intrusive Suite is dominated by rocks with <65 percent SiO_2; these have the highest levels of other major elements except Na_2O and K_2O. Amongst the siliceous granitoid rocks, the Big River Granite and Bayhead granite show the greatest range of major-element compositions. Other units within the Strawberry Intrusive Suite, and all units within the Lanceground Intrusive Suite, have restricted SiO_2 contents in the range of 70 to 77 percent.

TiO_2 and P_2O_5 define separate trends for the northern and southern zones of the Numok Intrusive Suite that coalesce at about 65 percent silica; the northern zone is enriched in both relative to the southern zone. N/N+K [$Na_2O/(Na_2O + K_2O)$] ratios show a pronounced negative trend against SiO_2 in the Numok Intrusive Suite, indicating relative enrichment of K_2O with differentiation, as might be expected, but are approximately constant in other units. N/N+K is almost invariably ≤ 0.5 above 70 percent SiO_2, except in a few Na-enriched samples from the Strawberry Intrusive Suite.

K+N/A (agpaitic index) values are generally > 0.95, and both the Strawberry and Lanceground Intrusive suites include some peralkaline compositions. A/C+N+K ratios increase smoothly with SiO_2 (reflecting decreasing Ca for the most part), and parts of the Strawberry Intrsuive Suite (notably the Bayhead granite) are weakly peraluminous. However, none of the units are dominated by peraluminous rocks. All units show high F/F+M (generally ≥ 0.85), with the exception of parts of the Numok Intrusive Suite. They lie above the calc-alkaline field indicated by Anderson (1983), and are akin (in this respect, at least) to his 'anorogenic granite' association, characterized by variable but consistent iron enrichment.

Ternary AFM and CNK projections (Figure 23) demonstrate a superficial calc-alkaline trend for all units. Note the alkali-rich nature of even the silica-deficient rocks in the Numok Intrusive Suite; almost all samples cluster in alkali-rich areas of the diagrams. Alkali-lime indices (SiO_2 content at which Na_2O+K_2O = CaO) are difficult to calculate, as very few samples have CaO >(Na_2O + K_2O). Linear regression of all posttectonic Makkovikian data suggests a value of about 55 percent SiO_2 or less, i.e., alkali-calcic in the terminology of Peacock (1931). The CNK diagram also illustrates minor alkali disturbance in the Strawberry Intrusive Suite, but not to the extent of that observed in the Kennedy Mountain Intrusive Suite.

Trace-Element Patterns

Compatible trace elements (Figures 24 and 25) such as V, Cr, Cu, Ni, and Sc (typified by the behaviour of V), all show strong inverse correlations with SiO_2. These elements do not discriminate between units.

Incompatible LFS elements (e.g., Rb and Th, Figure 24) provide relatively little distinction between units. Rb defines two trends in the Numok Intrusive Suite; many rocks with < 65 percent SiO_2 in the southern zone show Rb contents similar to those of siliceous granitoid units with over 70 percent SiO_2. Rb and Th are, however, enriched in Strawberry Intrusive Suite granites, and are very scattered above ca. 70 percent SiO_2. Similar disorganized variation is shown by U and Pb (not shown).

Sr and Ba show inverse trends against SiO_2 that suggest fractionation of feldspars. Sr is highest in parts of the Numok Intrusive Suite, particularily the southern area, where the plagiophyric monzonite unit is probably partly a plagioclase cumulate. Ba patterns define separate trends for the geographic zones of the Numok Intrusive Suite. The northern zone shows a rapid decrease in Ba with SiO_2 up to ca. 65 percent SiO_2, where its trend coalesces with the shallower trend of the southern zone. These suggest differences in their fractionation histories.

High-Field-Strength (HFS) trace elements, for example, Zr and Nb, have similar patterns in most units. High-silica granites of the Strawberry and Lanceground Intrusive suites show extreme variation in both elements, but are generally enriched compared to the Big River Granite. Zr and Nb levels in the Numok Intrusive Suite show very little contrast with the siliceous granitoid rocks, considering the differences in their major element compositions. Syenites from the southern zone have high Zr contents similar to those shown by the Lanceground Intrusive Suite.

Table 5. Average compositions of posttectonic Makkovikian plutonic rocks, subdivided by principal unit

ANALYSES	1		2		3		4		5		6		7		8	
n^1	42		15		18		22		10		57		42		7	
n^2	10		2		4		2		3		35		38		6	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	64.98	4.21	59.64	4.32	64.31	5.04	66.73	2.80	57.60	2.33	69.78	5.20	72.85	3.56	70.59	3.83
TiO_2	0.73	0.35	0.83	0.23	0.72	0.40	0.54	0.17	0.91	0.21	0.43	0.33	0.21	0.11	0.26	0.09
Al_2O_3	15.62	1.28	17.76	1.70	15.35	1.41	14.79	1.00	17.87	0.77	13.94	1.27	12.99	1.42	14.54	1.71
Fe_2O_3	1.43	0.67	2.00	0.82	1.40	0.74	1.47	0.47	2.10	0.39	1.05	0.75	1.14	0.80	1.14	0.59
FeO	3.22	1.24	3.60	0.99	4.07	2.14	3.24	1.36	4.45	1.02	2.37	1.47	1.34	0.82	1.37	0.56
MnO	0.13	0.06	0.10	0.03	0.17	0.09	0.13	0.05	0.11	0.02	0.07	0.05	0.06	0.06	0.07	0.06
MgO	0.72	0.54	1.71	1.20	0.49	0.43	0.31	0.14	2.35	0.62	0.51	0.61	0.29	0.62	0.28	0.14
CaO	2.05	0.92	3.78	1.68	1.90	0.88	1.61	0.54	5.02	1.09	1.49	1.08	0.96	1.33	0.95	0.21
Na_2O	4.68	0.53	4.45	0.29	4.56	0.77	4.46	0.37	4.44	0.73	3.95	0.71	4.16	1.26	4.18	0.57
K_2O	5.35	0.77	4.92	1.40	5.93	0.86	5.68	0.47	4.01	0.57	5.07	1.04	4.92	1.15	5.76	1.16
P_2O_5	0.21	0.17	0.27	0.11	0.20	0.19	0.10	0.06	0.32	0.08	0.10	0.11	0.03	0.03	0.07	0.04
LOI	0.50	0.21	0.65	0.48	0.49	0.27	0.42	0.19	0.76	0.42	0.59	0.19	0.62	0.35	0.56	0.12
TOTAL	99.62		99.71		99.59		99.48		99.94		99.35		99.57		99.77	
(ppm)	Trace elements															
Li	20.0	12.3	22.1	7.1	14.7	9.8	11.3	5.5	18.5	4.9	22.5	18.7	29.7	26.2	20.6	6.5
F	732.0	404.6	1125.7	468.1	465.6	312.3	390.1	228.4	696.9	370.5	922.9	723.5	1669.0	942.8	893.9	558.7
Sc	10.5	3.5	10.5	0.7	14.9	7.1	7.0	0.6	10.8	3.9	4.6	4.3	1.6	1.5	3.9	1.8
V	33.5	25.2	78.2	49.7	20.1	11.9	15.4	8.0	103.6	29.7	28.9	30.4	22.2	47.7	14.4	9.1
Cr	3.1	3.9	10.9	16.0	2.0	1.2	4.8	3.5	22.1	9.1	4.7	4.8	5.8	7.4	8.4	12.7
Ni	1.3	0.5	6.1	8.8	1.0	0.0	1.2	1.1	11.8	4.1	2.1	3.5	2.6	6.6	1.9	1.6
Cu	6.7	3.6	20.5	15.5	7.5	4.5	5.3	1.7	34.6	9.1	4.6	4.1	13.2	51.2	5.3	3.6
Zn	93.5	26.2	79.1	20.7	107.9	42.4	120.7	46.0	79.4	13.7	74.0	38.8	84.7	70.5	115.7	149.5
Ga	20.2	3.6	20.7	2.3	20.8	2.6	22.5	10.0	19.7	2.3	17.4	7.0	17.1	7.3	18.4	6.1
Rb	102.4	42.3	141.3	53.4	94.8	55.9	126.8	53.0	109.5	31.2	151.7	63.6	181.7	64.0	170.3	33.3
Sr	204.8	132.2	453.9	201.0	114.9	75.1	102.1	79.0	512.1	103.2	119.4	110.4	66.5	67.0	113.6	73.5
Y	39.6	12.9	38.8	14.2	33.4	15.5	73.6	24.2	34.0	4.5	57.1	37.3	66.8	48.2	46.7	6.6
Zr	460.1	260.2	564.6	233.9	577.8	446.6	951.0	328.7	352.6	236.5	467.8	399.5	447.2	314.1	454.6	166.0
Nb	18.0	7.2	20.3	9.8	15.3	5.3	27.3	8.5	15.7	3.6	25.7	13.2	30.8	36.3	21.4	2.2
Mo	3.9	1.1	4.3	0.8	2.9	0.9	3.9	1.3	4.1	1.0	4.3	1.8	3.9	2.2	3.3	1.4
Sn	2.4	2.5	3.0	2.8	1.5	1.0	1.0	0.0	2.3	1.5	4.0	2.9	5.3	3.3	3.7	3.0
Cs	1.9	2.3	1.3	1.1	0.9	0.8	0.5	0.0	1.5	0.9	1.2	1.1	1.1	0.7	1.4	1.1
Ba	1134.0	804.3	1063.9	311.6	743.2	656.5	832.2	427.6	860.3	166.7	706.4	479.6	327.7	266.4	504.0	220.6
La	73.4	46.3	56.2	17.2	60.9	28.6	93.4	24.3	53.8	6.5	101.5	108.0	78.0	43.8	105.3	46.9
Ce	144.2	87.0	117.7	39.5	115.9	56.8	196.8	52.6	104.5	18.0	198.5	199.2	161.7	81.5	196.3	83.1
Sm	11.5	4.8	15.0	1.4	11.5	1.3	17.5	6.4	8.8	0.7	13.1	7.3	12.9	6.7	14.2	4.5
Yb	3.3	1.7	4.3	2.5	2.5	0.0	8.0	0.0	2.5	0.0	5.3	2.2	8.2	5.5	5.3	2.2
Hf	8.7	5.5	15.0	1.4	11.5	7.1	17.0	2.8	7.7	1.2	11.0	6.5	13.6	8.1	13.3	4.0
Pb	16.3	6.9	15.5	6.3	14.5	6.8	17.1	7.4	13.2	3.7	23.6	7.9	22.5	9.8	26.9	9.5
Th	6.7	6.9	11.5	14.5	1.8	2.5	8.4	7.2	7.4	4.4	17.0	16.4	27.0	31.3	14.0	8.1
U	3.2	1.9	3.1	1.5	1.8	1.5	3.1	1.4	3.6	1.6	4.5	3.8	8.0	11.3	4.7	1.0
(Wt%)	CIPW norms (partial)															
Q	11.33	8.12	4.70	4.67	7.14	9.46	14.40	6.02	2.40	2.11	23.06	9.88	27.54	8.62	21.90	10.29
C	0.00	0.00	0.09	0.35	0.03	0.09	0.00	0.00	0.00	0.00	0.16	0.28	0.04	0.11	0.18	0.21
Or	31.90	4.54	31.03	5.07	31.19	7.99	33.84	2.79	23.86	3.36	30.30	6.19	29.36	6.81	34.26	6.93
Ab	39.95	4.43	37.96	2.52	42.45	8.60	38.11	3.11	37.68	5.85	33.79	6.08	35.17	10.88	35.25	4.03
An	5.84	3.12	12.89	5.84	6.97	5.74	3.58	1.81	17.11	3.99	5.00	2.93	2.33	1.66	3.46	1.57
Di	2.86	1.57	2.84	1.39	3.62	2.71	3.41	1.78	5.12	1.70	1.65	2.36	1.57	4.86	0.40	0.85
Hy	4.14	2.01	4.91	2.50	3.22	2.54	3.22	1.61	7.03	3.99	3.39	2.15	1.48	1.39	1.80	0.98
Ol	0.01	0.08	0.80	2.09	1.21	2.72	0.00	0.00	1.12	2.37	0.02	0.13	0.00	0.03	0.00	0.00
Mt	2.09	0.97	2.72	0.94	2.15	0.94	1.96	0.62	3.06	0.58	1.51	1.04	1.25	0.90	1.66	0.87
Il	1.40	0.68	1.56	0.44	1.38	0.66	1.04	0.32	1.73	0.40	0.83	0.64	0.41	0.22	0.50	0.17

KEY TO ANALYSES (NIS–Numok Intrusive Suite. SIS–Strawberry Intrusive Suite)

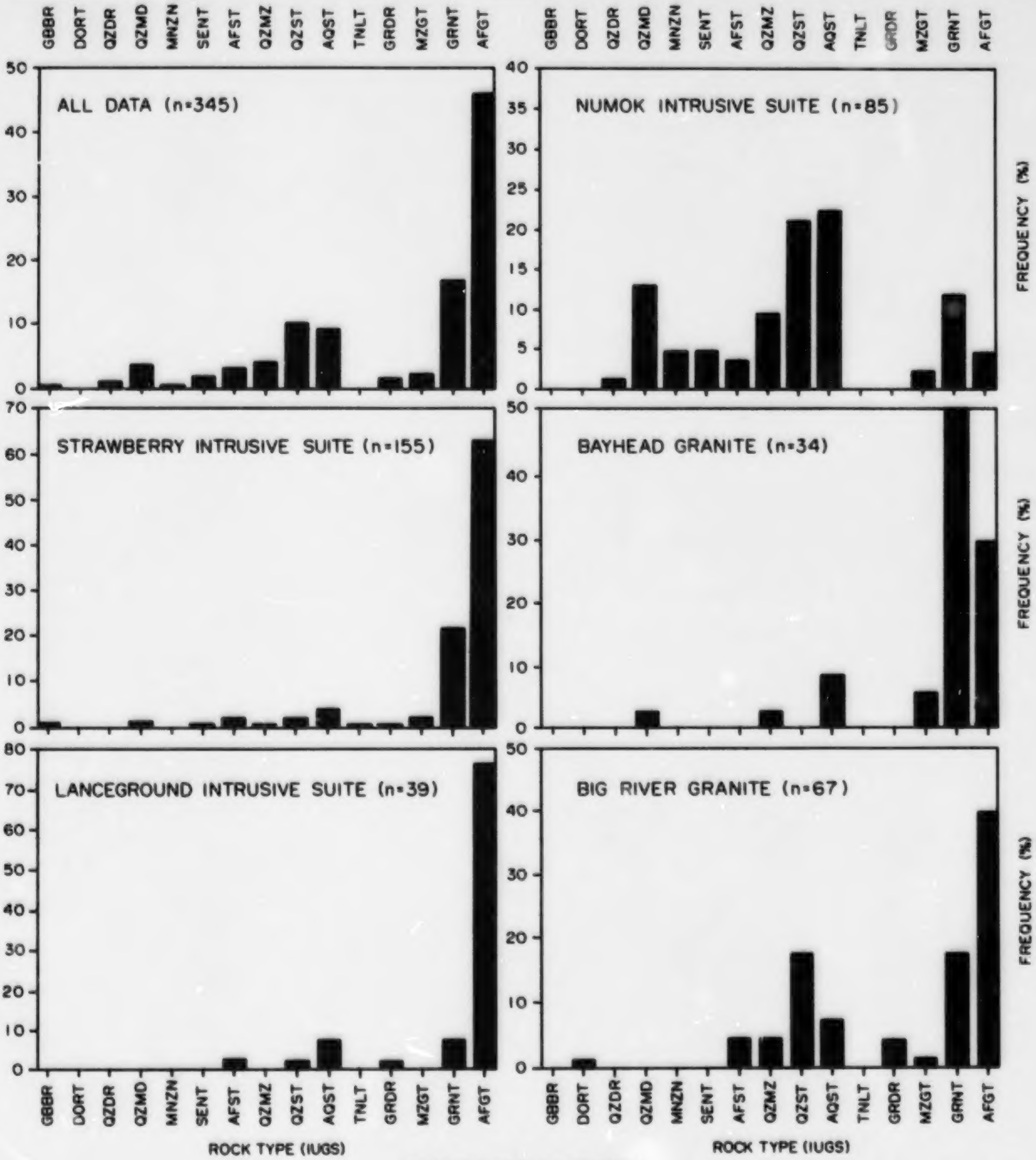
1 (NIS) Monzonite to quartz monzonite (Northern Zone)
2 (NIS) Monzonite to quartz monzonite (Southern Zone)
3 (NIS) Syenite to quartz syenite (Northern Zone)
4 (NIS) Syenite to quartz syenite (Southern Zone)
5 (NIS) Plagiophyric monzodiorite and monzonite
6 (SIS) Bayhead granite
7 (SIS) Cape Strawberry granite
8 (SIS) October Harbour granite
n^1 number of analyses for all elements except those listed below
n^2 number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 5. *(Continued)*

9		10		11		12		13		14		15		16	
4		33		50		22		19		41		64		15	
3		31		29		20		15		31		13		0	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
74.58	0.83	70.80	5.02	71.99	4.15	72.50	2.01	70.12	3.39	72.84	2.75	69.00	5.09	74.81	1.47
0.14	0.04	0.32	0.36	0.28	0.15	0.26	0.07	0.44	0.32	0.30	0.11	0.44	0.21	0.16	0.08
13.14	1.39	13.91	1.40	13.64	1.76	13.16	0.77	13.76	1.72	12.99	1.34	14.75	1.77	13.09	0.65
1.43	1.28	0.95	0.94	1.00	0.51	1.10	0.50	1.65	0.74	1.07	0.39	1.25	0.57	0.78	0.18
0.34	0.23	1.92	2.37	1.20	0.80	1.30	0.56	1.79	1.35	1.35	0.68	1.72	0.93	0.49	0.26
0.03	0.01	0.06	0.08	0.05	0.04	0.05	0.02	0.09	0.05	0.06	0.03	0.07	0.04	0.04	0.02
0.11	0.06	0.26	0.36	0.31	0.27	0.17	0.21	0.23	0.15	0.17	0.15	0.59	0.91	0.13	0.11
0.51	0.34	1.06	0.81	0.95	0.73	0.77	0.38	1.14	0.60	0.82	0.42	1.56	1.25	0.53	0.30
3.52	0.50	4.08	0.48	4.11	0.68	3.95	0.43	4.09	0.68	3.92	0.66	4.21	0.72	4.59	0.84
5.76	0.60	5.41	1.25	5.15	0.69	5.58	0.41	5.46	1.57	5.42	0.67	5.25	0.92	4.47	1.18
0.01	0.01	0.07	0.11	0.06	0.08	0.04	0.03	0.07	0.07	0.04	0.02	0.11	0.07	0.03	0.03
1.44	1.97	0.62	0.18	0.79	0.26	0.56	0.11	0.56	0.30	0.50	0.18	0.61	0.31	0.49	0.12
101.01		99.46		99.53		99.44		99.40		99.48		99.56		99.61	
11.0	6.5	31.2	30.3	22.7	23.3	15.6	7.2	10.3	4.9	14.6	15.2	15.4	6.1	12.1	6.0
623.5	1106	1868.1	1455	1592.0	1256	1804.5	1069	941.4	879.6	1084.7	763.1	590.7	387.9	1105.4	533.5
0.6	0.2	4.0	6.6	2.5	1.6	2.5	1.7	7.0	10.2	3.2	1.7	2.4	0.9		
19.3	1.7	18.8	11.1	21.2	13.3	10.6	8.9	13.3	6.9	13.8	7.4	24.1	17.7	10.1	5.8
5.5	2.7	1.9	1.2	6.3	7.8	3.3	2.3	4.1	2.8	3.8	3.3	4.8	14.9	4.7	7.0
2.0	1.4	1.1	0.4	2.3	2.8	1.3	0.9	1.1	0.3	1.8	2.4	2.2	8.0	4.1	7.5
5.8	3.9	16.1	72.9	6.5	5.4	5.7	3.5	9.0	18.1	4.7	3.5	7.0	6.5	3.1	1.6
60.0	52.2	82.0	107.1	61.7	48.7	87.9	53.6	106.1	67.2	82.8	59.0	63.6	42.5	17.3	14.8
8.3	2.5	22.1	8.1	12.1	6.5	27.1	9.2	26.0	10.6	16.2	7.3	16.1	4.9	11.1	4.5
169.0	34.1	200.6	73.6	198.8	52.6	186.5	29.2	168.1	35.9	167.1	52.5	123.8	53.3	144.6	42.5
151.5	84.9	94.5	64.5	139.8	190.9	54.6	57.8	71.3	69.9	60.0	68.8	179.3	154.7	81.3	110.0
37.3	21.2	60.2	65.3	41.4	23.3	69.6	36.3	77.6	36.8	75.5	29.3	44.8	17.7	32.4	10.3
325.5	246.4	573.5	803.3	465.9	637.0	776.0	707.5	691.7	330.0	560.7	280.9	409.4	213.0	195.9	50.0
18.0	6.5	26.7	18.3	22.2	8.7	28.6	10.9	30.4	13.8	29.2	10.1	18.4	7.3	22.3	6.2
2.8	0.5	6.3	18.4	3.6	2.6	5.1	2.9	4.8	2.8	3.6	1.5	3.7	1.2	3.4	1.5
3.3	0.6	10.0	20.4	5.1	2.7	3.7	2.3	4.1	2.7	4.2	2.8	2.7	2.7		
1.1	0.5	0.7	0.5	1.7	1.5	1.1	0.7	1.1	0.6	1.1	0.7	0.7	0.6		
396.0	247.0	448.2	192.2	456.4	360.0	274.5	222.0	440.0	311.4	308.1	244.0	762.3	465.6	227.7	272.3
29.8	29.1	137.6	214.3	65.3	40.5	147.6	73.6	133.0	82.1	104.7	36.4	67.2	29.8	45.9	26.1
76.5	63.7	249.1	367.9	134.7	80.6	293.2	145.2	270.3	155.0	211.9	71.6	134.6	59.2	93.6	47.7
8.1	5.4	16.1	18.7	10.3	4.6	21.5	10.0	25.8	13.1	18.0	6.6	10.4	3.9		
4.8	2.3	7.1	6.9	6.0	2.5	7.8	4.7	10.5	5.7	8.5	2.9	4.2	2.0		
9.8	6.2	17.1	25.1	12.1	6.2	20.1	13.4	22.6	11.0	16.8	7.0	10.1	3.0		
26.8	3.6	113.6	500.5	18.8	10.2	23.6	11.0	25.0	18.9	24.7	12.0	19.4	11.5	10.1	4.6
6.8	1.7	20.7	22.8	12.8	9.3	16.4	7.4	14.3	7.0	22.3	7.3	13.0	10.2	13.1	6.5
3.0	0.7	5.4	3.3	5.3	2.8	5.2	2.0	4.1	1.6	6.3	2.4	4.2	2.7	5.9	2.0
30.86	4.00	23.27	8.74	26.17	8.48	26.46	4.40	23.17	10.42	27.49	7.01	20.30	10.05	30.06	2.46
0.19	0.16	0.06	0.12	0.16	0.28	0.03	0.09	0.35	1.45	0.01	0.05	0.07	0.15	0.02	0.07
34.17	3.56	31.23	3.82	30.83	4.12	33.33	2.43	32.53	9.25	32.33	3.97	31.35	5.43	26.65	7.01
29.87	4.30	35.21	3.75	35.09	5.63	33.64	3.65	34.66	5.96	33.46	5.51	35.93	6.02	39.13	7.19
2.53	1.82	3.63	1.93	3.21	3.18	1.70	1.58	2.26	1.88	1.84	1.57	5.69	4.27	1.88	1.67
0.00	0.00	1.18	2.03	0.88	1.38	1.51	1.34	1.98	1.71	1.50	1.17	1.28	1.80	0.40	0.24
0.36	0.26	2.34	3.54	1.35	1.17	0.85	0.89	1.16	1.50	0.92	0.89	2.16	1.22	0.29	0.52
0.00	0.00	0.07	0.38	0.06	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.22	1.78	0.00	0.00
0.71	0.52	1.40	1.40	1.35	0.73	1.53	0.77	2.03	1.00	1.50	0.57	1.74	0.84	0.97	0.34
0.21	0.04	0.64	0.73	0.53	0.28	0.50	0.14	0.85	0.62	0.57	0.20	0.84	0.41	0.31	0.16

KEY TO ANALYSES (LIS–Lanceground Intrusive Suite. SIS–Strawberry Intrusive Suite.)

- 9 (SIS) Poodle Pond granite
- 10 (SIS) Dog Islands granite
- 11 (SIS) Tukialik granite
- 12 (LIS) Lanceground Hills granite
- 13 (LIS) Pistol Lake granite
- 14 (LIS) Tarun granite
- 15 Big River Granite (porphyritic phase)
- 16 Big River Granite (equigranular phase)
- n^1 number of analyses for all elements except those listed below
- n^2 number of analyses for Sc, Sn, Cs, Sm, Yb and Hf



KEY TO ROCK TYPES

GBBR–Gabbro
DORT–Diorite
QZDR–Quartz diorite
QZMD–Quartz monzodiorite
MNZN–Monzonite
SENT–Syenite
AFST–Alkali feldspar syenite
QZMZ–Quartz monzonite
QZST–Quartz syenite
AQST–Alkali feldspar quartz syenite
TNLT–Tonalite
GRDR–Granodiorite
MZGT–Monzogranite
GRNT–Granite (ss)
AFGT–Alkali feldspar granite

Figure 21. *Relative abundance of IUGS rock types amongst posttectonic Makkovikian plutonic rocks, calculated from normative mineralogy using the method of Streckeisen and LeMaitre (1979). Note that this is based on Barth mesonorms, not the CIPW norms listed in tables. Regional and geological sample populations only.*

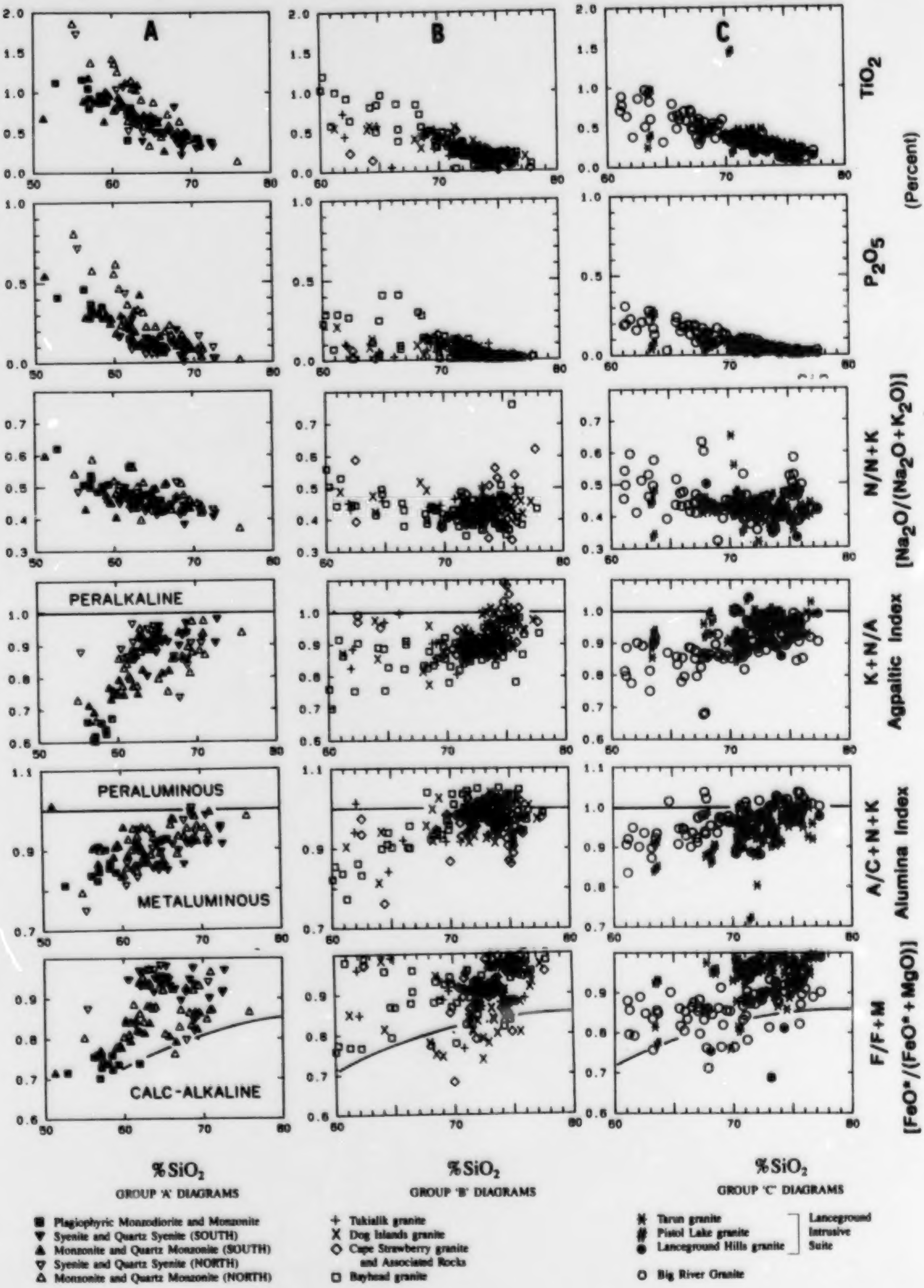


Figure 22. *Variation of selected major elements and derived ratios in posttectonic Makkovikian plutonic units.*

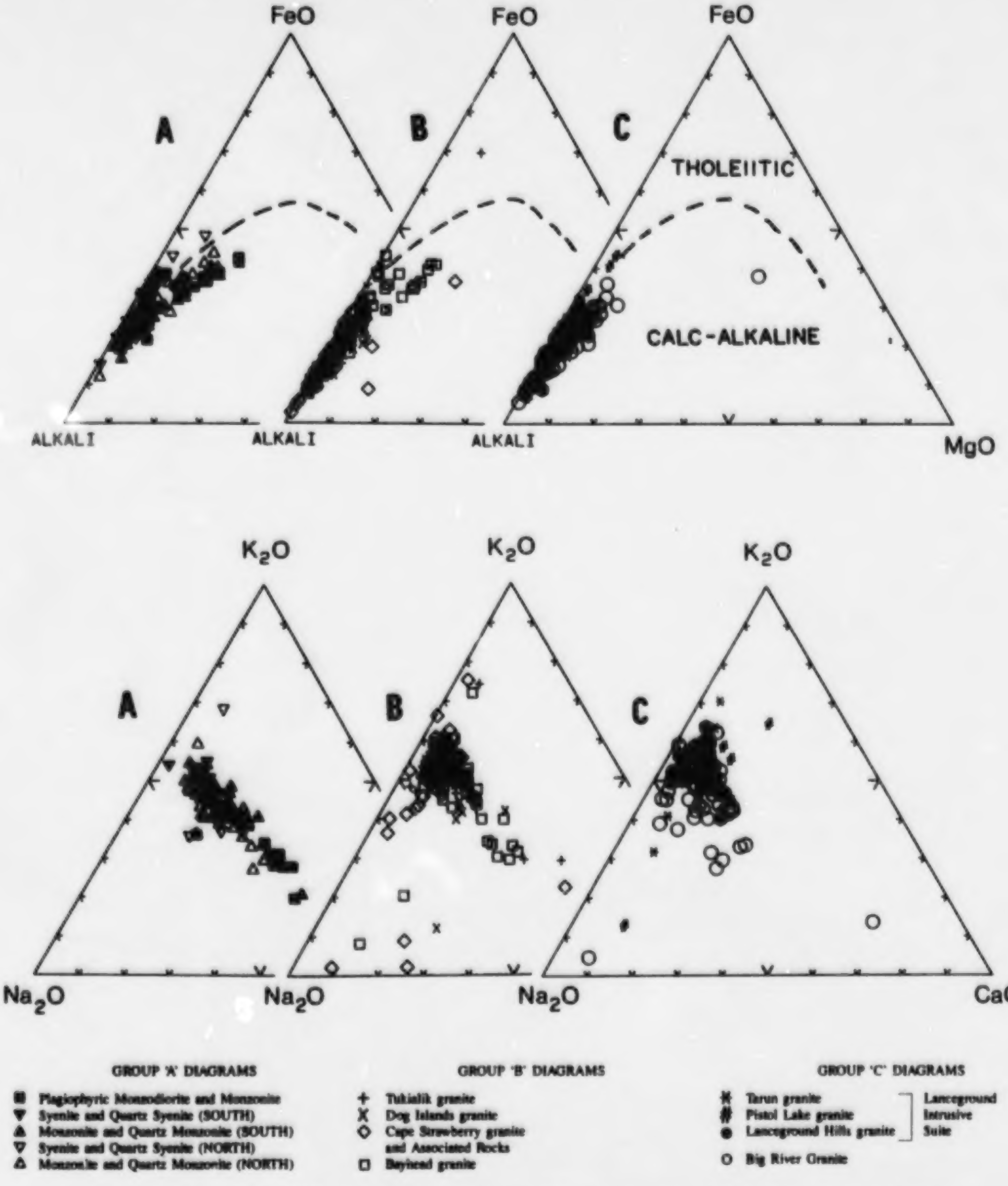


Figure 23. *AFM, CNK and QBF projections for posttectonic Makkovikian plutonic units.*

Variation patterns for Y are similar to those for Zr, and Y is also enriched in syenites of the Numok Intrusive Suite. La (also Ce) is enriched most strongly in the Lanceground Intrusive Suite, which has the highest overall REE contents (Table 5).

Fluorine shows strong variation, especially in rocks with >70 percent SiO_2. The Strawberry and Lanceground Intrusive suites, although highly variable at a sample level, show strong enrichment as a group (several samples containing >4000 ppm F are excluded from the figures). The Cape Strawberry granite of the Strawberry Intrusive Suite and the Lanceground Hills granite show the strongest F enrichment. Li (Figure 25) is enriched in the Strawberry Intrusive Suite relative to the Lanceground Intrusive Suite. Both suites, and syenites of the Numok Intrusive Suite, show local enrichment in Zn at high SiO_2 contents.

LABRADORIAN PLUTONIC ROCKS

Labradorian plutonic rocks are represented by 429 samples; 247 of these are regional samples collected on a 2-km-random-grid spacing. The remainder include 99 follow-

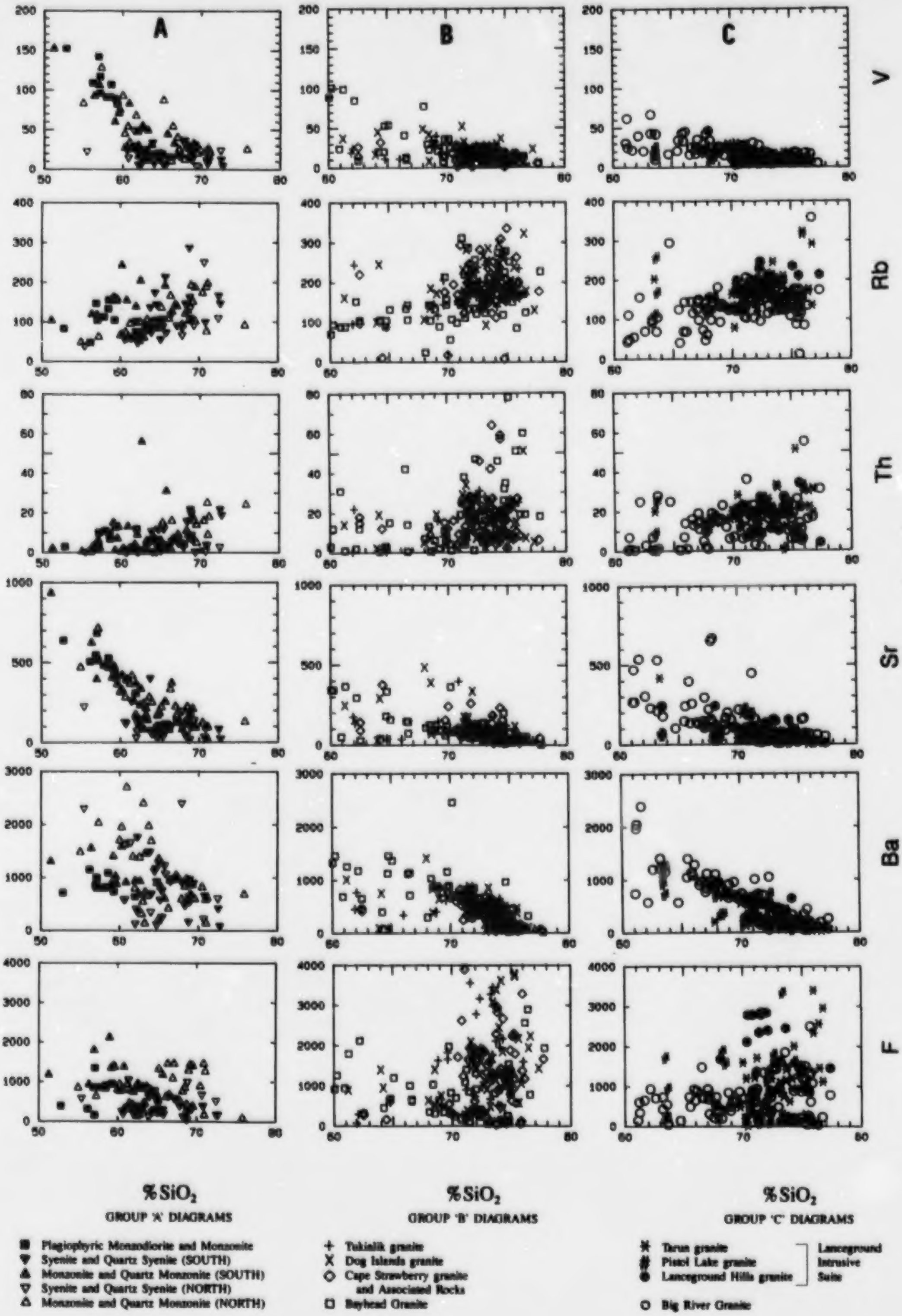


Figure 24. *V, Rb, Th, Sr, Ba and F vs SiO_2 in posttectonic Makkovikian plutonic units.*

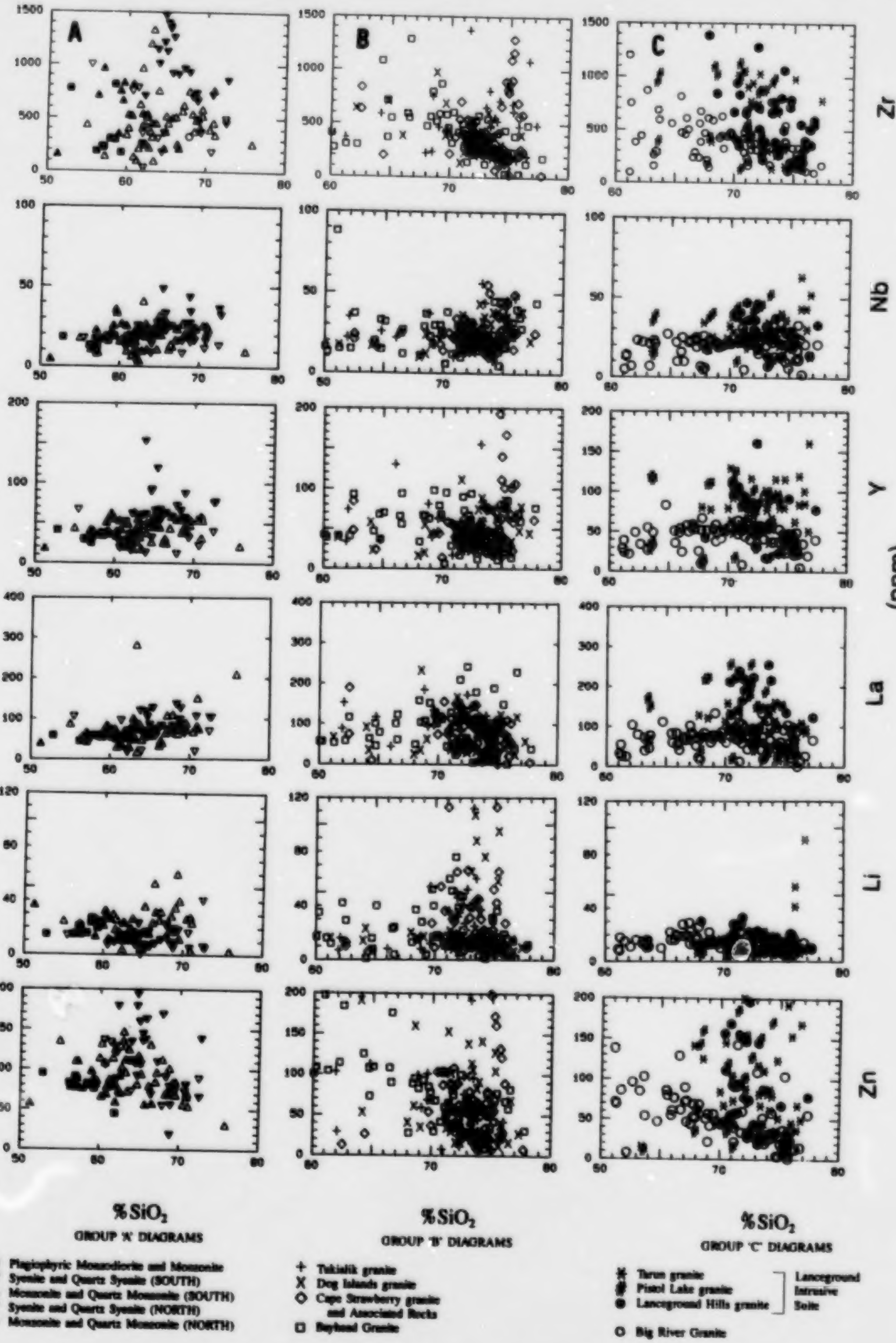


Figure 25. *Zr, Nb, Y, La, Li, Zn and F vs SiO_2 in posttectonic Makkovikian plutonic units*

up samples (mostly from the Monkey Hill, Adlavik and Mount Benedict Intrusive suites), and 83 samples distributed amongst all units.

General Geochemistry

Summary of Numerical Data

Average compositions of principal Labradorian plutonic units are listed in Table 6. Four main compositional groupings are apparent, and these are the Adlavik Intrusive Suite, the Mount Benedict Intrusive Suite, the Monkey Hill Intrusive Suite and the Otter Lake–Walker Lake granite.

The Adlavik Intrusive Suite is dominated by SiO_2-poor (< 60 percent) rocks, and has the highest levels of CaO, MgO, FeO and TiO_2 and 'compatible' trace elements; such features are to be expected in view of its mafic to intermediate composition. The various geographic divisions of the suite have similar mean compositions, except for the relatively siliceous gabbro at East Micmac Lake.

The Mount Benedict Intrusive Suite is dominated by rocks having 60 to 70 percent SiO_2. It is strongly enriched in Rb, Cs, U, Th, F and Zr compared to all other Labradorian units, and is enriched in Rb, Cs, U and Th relative to most Makkovikian units (e.g., Tables 4 and 5); this lithophile element enrichment is generally strongest in the syenite to granite unit. The least differentiated unit is similar in mean composition to diorite of the Adlavik Intrusive Suite.

The Monkey Hill Intrusive Suite consists of high-silica (72 to 75 percent SiO_2) granites that have low levels of CaO, FeO and MgO. However, trace-element patterns are relatively unevolved; Rb, Cs, U and Th abundances are moderate and F, Zr, La and Ce are depleted relative to most other units. Note that high mean Mo values for some plutons in these suites reflect inclusion of mineralized samples, and are not typical of the units as a whole. If these are excluded, Mo contents of these granites are indistinguishable from those of other units. Individual plutons are closely similar in composition, except for the Round Pond granite, which shows strong depletion of Zn, Sr, Y, Zr, Ba, La, Ce, Pb and Th. The Witchdoctor and Burnt Lake granites are generally similar in composition to granites of the Monkey Hill Intrusive Suite.

The Otter Lake–Walker Lake unit has unremarkable major- and trace-element characteristics, and shows no striking enrichment or depletion patterns.

Abundance and Distribution of Rock Types

IUGS rock types were calculated from normative data after Streckeisen and LeMaitre (1979). Labradorian plutonic rocks include a higher proportion of low-SiO_2 rock types than the Makkovikian assemblage, and are obviously bimodal (Figure 26). The Adlavik Intrusive Suite is dominated by gabbro, with lesser diorite to monzonite. The Mount Benedict Intrusive Suite overlaps this range, but is dominated by quartz monzonite to quartz syenite. The Monkey Hill Intrusive Suite and Witchdoctor and Burnt Lake granites are dominated by granite and alkali-feldspar granite. The Otter Lake–Walker Lake granite is dominated by monzogranite and granite. Mafic or intermediate rock types are essentially absent from the latter three associations, which are termed 'siliceous granitoid units' in subsequent discussions.

Geochemistry of the Adlavik Intrusive Suite

The Adlavik Intrusive Suite, because of its mafic-intermediate composition, merits a separate discussion. This subsection is based mostly on geochemical data from the main body at Adlavik Bay. Average compositions of textural and mineralogical facies from this area are listed in Table 7; the criteria used for subdivision are outlined below.

Subdivisions of the Suite

In addition to subdivision by subunit or 'facies', Table 4 also incorporates a second-order grouping based on the relative abundance of normative diopside (Di), hypersthene (Hy) and olivine (Ol). The basis for this division is as follows:

Rocks with well-preserved anhydrous mineral assemblages include both gabbronorite and gabbro variants, which appear to be discrete spatially. However, the widespread late magmatic and/or secondary hydrous mineral assemblages make it difficult to assess primary mineralogy in all areas via petrography.

A Di–Ol–Hy ternary projection (Figure 27) illustrates the presence of contrasting Hy-normative and Hy-free groups. Both contain variable normative Ol, but most of the Ol-free rocks are also Hy-normative. The diorite unit is also dominantly Hy-normative.

Examination of fresh samples where pyroxenes are well preserved suggests that there is good correspondance between normative and modal hypersthene; the CIPW norms therefore provide a method of classifying altered and hydrated samples, and those for which no petrographic data are available.

The distribution of Hy-normative and Hy-free variants appears to be geographically systematic (Figure 28). The leucogabbro facies is predominantly Hy-free, whereas the melagabbro facies is Hy-normative. The mafic cumulate facies contains both types. As expected, there are major-element geochemical contrasts between Hy-normative and Hy-free rocks, and also some trace element differences (Table 7).

It is suggested (on this rather tentative basis) that the Adlavik Bay intrusion can be divided into 'gabbronorite' and 'gabbro' sequences. The former includes the mafic cumulate facies, melagabbro facies and parts of the leucogabbro facies, and may be genetically associated with the Hy-normative diorite unit. The gabbro sequence includes most of the leucogabbro facies, and is considered to represent

Table 6. Average compositions of Labradorian plutonic rocks, subdivided by principal units

ANALYSES	1		2		3		4		5		6		7		8		9	
n^1	85		17		2		11		12		6		3		17		53	
n^2	15		1		0		0		2		2		1		1		22	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	49.94	4.57	48.03	1.82	55.55	0.35	49.77	3.34	58.21	3.21	56.46	2.79	58.43	1.33	55.52	3.22	64.46	4.46
TiO_2	0.94	0.44	1.03	0.32	0.60	0.01	1.15	0.46	0.82	0.31	0.86	0.21	0.80	0.12	0.97	0.20	0.61	0.24
Al_2O_3	15.80	3.98	14.81	3.23	16.24	1.49	15.79	2.61	17.86	1.26	18.61	1.08	17.44	0.67	18.23	1.64	16.03	0.93
Fe_2O_3	3.05	1.48	3.65	1.11	1.90	0.00	2.61	0.81	1.93	0.76	2.13	0.40	1.91	0.28	1.99	0.49	1.40	0.66
FeO	6.15	1.77	6.82	0.80	5.41	1.03	6.65	1.25	3.85	1.43	4.49	1.46	5.15	0.02	4.43	1.16	2.53	1.12
MnO	0.16	0.04	0.18	0.03	0.12	0.03	0.17	0.03	0.13	0.03	0.12	0.03	0.11	0.01	0.13	0.03	0.09	0.03
MgO	7.62	5.32	8.42	3.08	5.45	0.76	7.42	5.16	2.26	1.57	2.35	1.13	2.94	0.26	2.79	1.89	1.12	0.97
CaO	9.67	3.04	10.45	1.92	7.07	0.59	8.11	2.00	4.60	1.99	5.71	1.57	4.88	0.80	5.52	1.54	2.37	1.52
Na_2O	3.08	1.20	2.63	0.91	3.67	0.44	3.36	1.12	5.38	1.02	4.35	0.50	3.84	0.03	4.37	0.44	4.51	0.36
K_2O	1.47	0.92	1.51	0.48	2.05	0.25	2.17	1.07	3.40	0.97	3.39	1.31	3.42	0.26	3.61	0.95	5.41	0.93
P_2O_5	0.34	0.39	0.29	0.17	0.25	0.00	0.41	0.43	0.30	0.15	0.38	0.12	0.31	0.14	0.42	0.24	0.19	0.17
LOI	1.38	0.79	1.61	0.56	1.31	0.35	1.45	0.84	0.75	0.31	0.94	0.31	1.19	1.16	1.26	0.56	0.84	0.23
TOTAL	99.60		99.43		99.62		99.06		99.49		99.79		100.42		99.24		99.56	
(ppm)	Trace elements																	
Li	21.7	9.2	21.7	6.4	18.5	2.1	31.0	9.9	20.6	7.8	20.0	4.0	22.3	2.5	32.7	12.4	31.0	10.4
F	732.6	1120	873.5	393.0	385.0	62.2	654.4	317.9	804.8	340.9	913.3	353.4	716.7	127.2	975.1	365.5	1298.0	410.7
Sc	32.3	16.2	32.9						15.0	0.0	16.9	9.8	12.0		6.7		5.8	2.1
V	203.5	110.6	223.8	68.0	172.0	36.8	183.2	56.2	79.3	67.7	117.0	41.9	97.7	66.7	107.9	39.5	50.6	40.9
Cr	275.8	444.3	288.1	276.5	171.5	46.0	338.9	463.7	29.7	34.4	19.2	13.6	23.7	2.1	42.3	81.7	14.5	16.6
Ni	78.2	128.4	57.2	41.4	45.5	6.4	98.3	150.9	11.0	12.0	8.3	5.4	15.3	0.6	20.7	43.2	4.3	5.3
Cu	50.7	41.0	48.9	23.2	88.5	37.5	50.0	35.1	18.8	14.4	33.0	18.4	18.0	11.3	56.9	40.0	18.9	16.9
Zn	96.7	40.1	97.4	22.0	75.5	3.5	100.9	22.7	75.7	19.6	83.8	10.2	71.0	13.2	92.1	25.5	60.3	19.1
Ga	20.5	6.1	19.9	3.6	20.5	0.7	18.9	5.2	16.3	5.6	21.7	1.4	17.7	0.6	19.4	4.5	11.3	4.7
Rb	41.6	29.9	44.1	18.0	42.5	0.7	56.6	31.5	73.8	23.5	83.5	26.8	91.7	6.7	130.0	46.4	233.2	81.8
Sr	760.5	297.8	661.5	382.2	804.0	234.8	677.5	182.0	687.0	225.6	612.3	125.0	615.0	150.7	766.5	216.7	308.9	191.0
Y	19.2	10.5	23.2	6.5	11.0	4.2	19.3	9.7	21.3	6.9	33.5	9.3	17.0	1.7	24.7	6.8	30.3	8.7
Zr	73.1	64.4	115.4	79.9	87.5	1.0	116.3	87.5	99.3	58.5	351.0	159.1	116.0	12.3	236.0	190.9	408.0	190.7
Nb	3.6	4.2	3.9	4.2	2.0	0.0	3.4	2.7	10.2	3.5	13.2	6.6	5.0	0.0	10.7	5.0	21.2	8.1
Mo	3.4	1.1	5.7	8.6	3.0	0.0	4.0	2.5	3.1	0.7	4.2	2.1	3.3	0.6	4.7	3.5	4.7	1.5
Sn	1.0	0.0	1.0						1.0	0.0	1.5	0.7	1.0		14.0		6.1	4.2
Cs	1.1	1.7	0.5						1.3	1.1	2.0	0.0	0.5		6.4		10.7	5.3
Ba	597.9	338.3	504.5	227.8	983.5	79.9	940.1	839.7	1734.6	1297	902.8	209.2	855.0	113.5	1115.7	409.1	742.8	360.6
La	22.5	14.6	28.8	18.6	30.5	2.1	28.6	15.6	34.8	9.8	47.2	9.5	28.7	5.1	44.0	10.5	50.7	13.1
Ce	48.0	30.2	55.7	39.9	55.5	3.5	54.4	32.4	61.1	23.5	96.5	29.6	58.0	8.0	89.9	22.5	108.3	30.3
Sm	5.4	2.2	8.1						6.5	0.5	7.1	0.3	5.4		10.1		8.2	1.7
Yb	2.5	0.0	2.5						2.5	0.0	2.5	0.0	2.5		4.5		4.1	1.0
Hf	2.3	2.0	1.0						3.0	0.0	3.5	0.7	3.0		20.0		12.2	3.0
Pb	5.2	7.0	1.9	1.7	8.5	0.7	3.8	3.8	9.4	4.2	10.7	4.3	7.0	5.2	12.5	4.6	17.8	6.1
Th	2.2	2.9	1.3	1.3	1.5	0.7	1.7	1.9	3.1	3.8	7.0	4.3	12.3	9.0	7.8	5.5	21.6	13.6
U	1.0	0.9	1.1	0.8	0.9	0.1	1.2	1.0	1.8	1.3	3.2	1.3	1.8	0.1	3.3	1.7	6.8	3.2
(Wt%)	CIPW norms (partial)																	
Q	0.81	2.64	0.00	0.00	2.82	0.80	0.05	0.00	1.60	2.92	2.57	3.67	6.68		1.10	1.85	10.94	6.32
C	0.03	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57		0.00	0.00	0.02	0.10
Or	8.80	5.30	9.09	2.90	12.31	1.48	13.06	0.18	20.32	5.84	20.24	7.84	20.34		21.71	5.63	32.33	5.51
Ab	24.81	10.83	20.09	7.20	31.56	3.88	27.11	2.46	45.78	8.57	37.13	4.27	32.71		37.43	3.77	38.63	3.09
An	25.29	9.12	24.67	5.39	22.12	2.98	22.08	0.25	14.73	5.61	21.48	6.27	18.85		19.86	5.90	7.58	4.35
Ne	0.89	1.35	1.42	1.84	0.00	0.00	1.08	0.00	0.14	0.35	0.02	0.05	0.00		0.13	0.35	0.00	0.00
Di	17.21	12.49	21.39	10.65	9.98	4.68	13.48	0.86	5.51	4.30	4.17	2.82	3.19		4.71	2.44	2.60	2.33
Hy	5.20	6.01	4.15	6.40	16.63	1.49	2.59	0.47	5.10	4.25	7.27	4.79	12.60		7.01	4.62	3.90	2.08
Ol	9.70	10.15	11.02	3.55	0.00	0.00	13.38	2.26	1.69	2.73	1.42	2.69	0.00		2.18	3.19	0.25	1.80
Mt	4.50	2.21	5.40	1.65	2.80	0.01	3.87	0.13	2.83	1.11	3.12	0.58	2.79		2.95	0.73	2.03	0.96
Il	1.82	0.86	2.00	0.63	1.15	0.02	2.23	0.03	1.57	0.61	1.66	0.39	1.53		1.89	0.39	1.17	0.47

KEY TO ANALYSES (AIS–Adlavik Intrusive Suite) (MBIS–Mount Benedict Intrusive Suite)

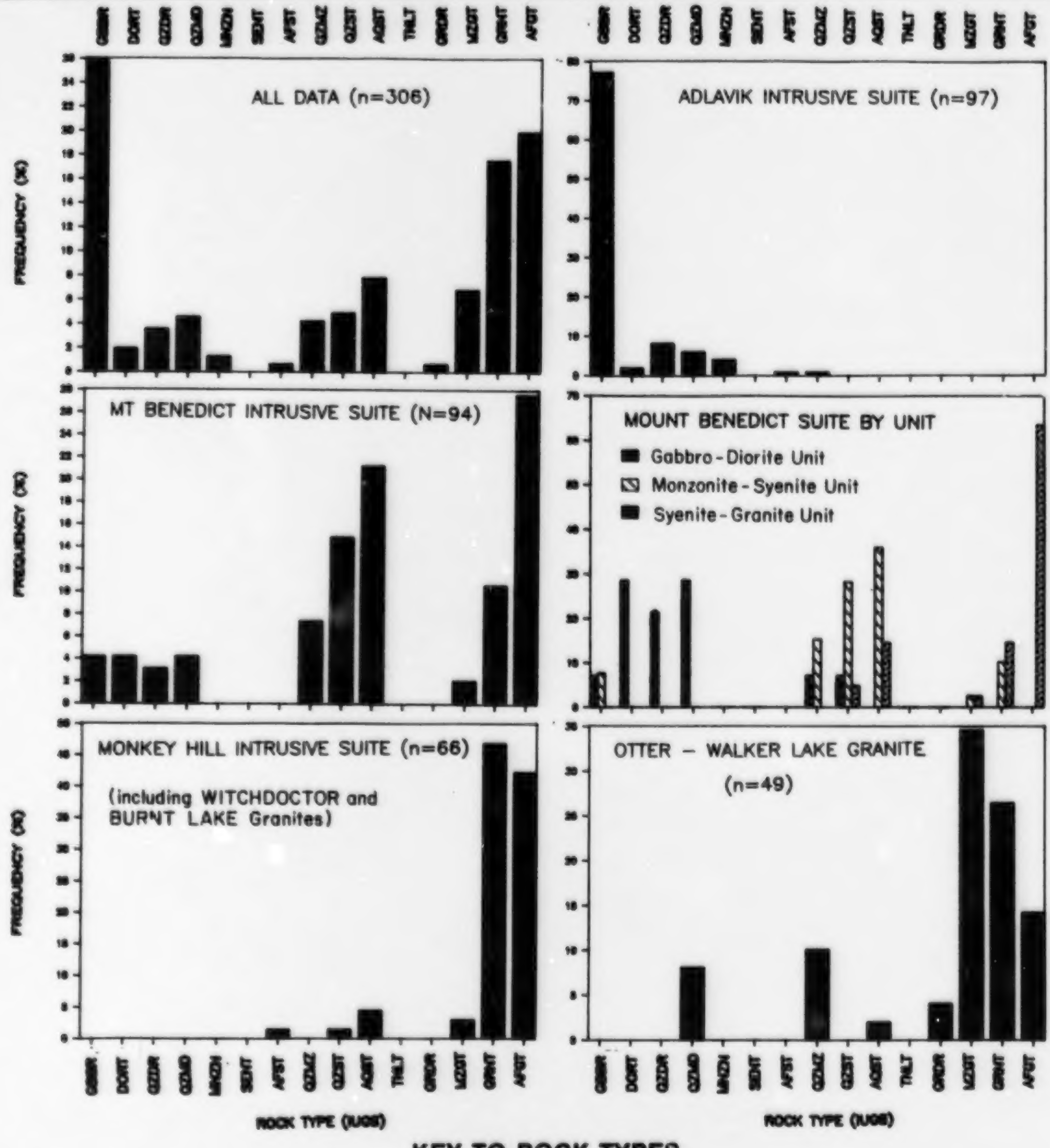
1 (AIS) Gabbro-gabbronorite (Type Area)
2 (AIS) Gabbro-gabbronorite (Southern Area)
3 (AIS) Gabbro-gabbronorite (East Micmac)
4 (AIS) Gabbro-gabbronorite (Eastern Area)
5 (AIS) Diorite (Type Area)
6 (AIS) Diorite (Southern Area)
7 (AIS) Diorite (East Micmac)
8 (MBIS) Gabbro to monzodiorite
9 (MBIS) Monzonite, syenomonzonite, syenite
n^1 Number of analyses for all elements except those listed below
n^2 Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 6. *(Continued)*

10		11		12		13		14		15		16		17		18		19	
67		17		17		49		33		4		8		13		3		6	
39		12		17		11		29		2		6		10		3		5	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
70.69	3.31	73.78	3.33	72.71	3.11	68.54	4.42	72.97	5.86	75.69	1.69	72.49	2.89	74.62	2.44	72.77	3.16	74.05	0.68
0.30	0.18	0.15	0.15	0.16	0.07	0.44	0.20	0.14	0.14	0.04	0.01	0.14	0.12	0.12	0.07	0.18	0.09	0.18	0.04
14.39	1.06	13.77	1.22	14.18	1.74	14.98	1.62	13.39	1.48	12.75	0.21	13.82	1.11	13.47	0.84	14.38	0.94	13.59	0.13
0.97	0.40	0.65	0.59	0.57	0.25	1.20	0.61	1.57	4.65	0.42	0.07	0.78	0.78	0.55	0.23	0.59	0.62	0.66	0.28
1.09	0.66	0.63	0.26	0.60	0.36	1.87	1.01	0.88	2.23	0.12	0.08	0.58	0.47	0.49	0.52	0.90	0.40	0.84	0.23
0.05	0.02	0.04	0.01	0.03	0.01	0.06	0.03	0.06	0.04	0.01	0.00	0.04	0.02	0.04	0.02	0.04	0.03	0.04	0.01
0.38	0.27	0.15	0.12	0.21	0.14	0.86	0.34	0.21	0.22	0.06	0.02	0.15	0.13	0.26	0.37	0.26	0.20	0.35	0.28
0.97	0.49	0.75	0.41	0.80	0.30	2.04	1.02	0.75	0.54	0.38	0.10	0.84	0.29	0.80	0.36	1.01	0.42	0.86	0.16
4.28	0.43	4.13	0.40	4.40	1.53	3.89	0.55	4.23	0.85	4.34	0.28	4.78	2.50	4.24	0.25	4.13	0.25	3.84	0.65
5.58	0.51	5.04	0.64	4.93	1.07	4.70	0.62	4.69	1.23	4.33	0.44	4.59	1.89	4.58	0.37	4.99	0.27	4.98	1.18
0.05	0.06	0.02	0.03	0.03	0.02	0.15	0.09	0.03	0.04	0.01	0.00	0.04	0.03	0.03	0.04	0.06	0.04	0.04	0.01
0.75	0.11	0.45	0.14	0.54	0.10	0.77	0.24	0.63	0.20	0.50	0.11	0.72	0.44	0.54	0.33	0.47	0.19	0.43	0.13
99.50	99.56	99.16	99.50	99.55	98.65	98.97	99.74	99.78	99.86										
25.3	11.0	14.3	13.6	27.2	23.1	25.7	12.5	24.1	14.6	5.5	1.0	13.1	5.4	15.0	5.6	16.7	3.5	32.8	15.8
1240.5	617.4	137.9	97.7	217.5	130.7	679.1	257.1	685.2	463.3	258.3	201.4	199.4	194.1	369.5	295.0	119.3	109.6	780.2	502.0
2.9	1.7	2.3	1.4	1.6	1.0	6.8	2.4	1.3	0.8	0.3	0.0	1.9	1.2	0.7	0.3	1.6	0.9	2.5	0.9
23.1	13.1	13.1	5.7	16.3	7.7	44.6	30.2	17.7	24.9	12.0	5.3	20.1	7.1	14.8	11.1	22.0	7.2	19.3	8.2
6.5	3.8	3.8	4.9	3.2	2.3	6.5	7.0	3.7	2.4	2.0	0.8	1.8	1.0	7.9	13.6	1.0	0.0	3.7	4.4
1.9	1.7	1.8	2.3	1.5	1.9	2.1	3.0	1.2	0.7	1.0	0.0	1.0	0.0	2.3	2.8	1.0	0.0	1.0	0.0
10.1	8.8	3.4	2.6	4.2	4.6	9.1	18.7	11.1	25.2	11.8	7.4	15.9	28.7	5.4	6.7	3.3	2.3	3.0	3.2
39.9	14.0	25.1	8.2	32.5	12.1	46.9	21.4	42.5	40.3	9.0	3.2	24.3	13.0	29.5	13.9	35.7	4.7	40.5	12.5
8.6	2.1	11.5	7.1	11.9	4.1	12.8	4.1	12.8	8.6	11.3	2.6	11.3	4.7	9.7	3.3	13.7	1.2	13.0	4.7
315.3	81.3	169.5	49.6	212.8	78.4	140.5	38.7	201.1	77.7	184.8	38.9	119.5	51.2	160.1	31.7	102.0	11.5	229.3	44.1
126.8	108.3	75.4	83.5	98.8	67.7	277.7	154.8	156.2	294.4	29.0	16.8	130.1	101.9	145.6	79.7	176.7	110.0	95.2	20.1
27.8	7.6	23.7	27.5	27.1	6.2	28.2	10.2	34.5	30.1	11.5	1.3	20.3	11.9	20.5	7.4	12.0	2.7	25.0	7.4
345.0	140.0	198.5	232.5	172.7	82.7	240.0	83.8	178.1	111.4	100.3	31.9	155.3	80.7	116.0	53.8	123.3	14.5	219.0	48.1
29.0	8.6	16.9	16.4	25.1	8.0	13.6	4.4	19.6	10.4	17.0	9.7	13.3	2.7	15.1	4.6	8.7	3.8	20.7	2.2
4.3	2.7	3.4	0.9	52.8	202.1	3.2	1.2	146.1	826.9	2.3	1.0	129.1	356.7	1.9	0.5	2.3	0.6	1.8	1.0
7.2	4.2	1.8	1.1	2.8	2.5	3.9	3.3	3.0	2.2	1.0	0.0	1.8	1.6	2.4	2.1	1.0	0.0	5.4	2.6
9.0	4.3	1.8	1.2	2.0	1.4	4.1	1.8	3.0	2.5	0.5	0.0	1.0	0.8	1.6	1.3	0.5	0.0	2.4	1.2
381.9	352.6	515.1	912.7	522.9	328.7	961.5	542.3	343.9	263.8	47.0	21.4	589.0	339.6	292.6	387.7	892.0	549.1	424.8	160.8
56.3	22.9	28.0	25.9	34.3	17.6	50.6	14.8	22.8	21.5	3.8	3.5	24.9	22.9	16.2	9.5	14.7	10.3	37.3	22.2
114.0	43.7	60.9	55.4	65.9	33.2	100.1	28.5	49.8	47.7	4.0	4.8	46.1	38.6	30.9	18.5	30.3	13.6	79.0	37.2
6.9	1.7	3.9	1.4	4.4	2.2	9.3	3.0	5.1	4.9	1.0	0.4	5.1	2.7	2.5	0.9	2.7	0.6	5.3	2.2
4.5	0.9	2.5	0.0	3.0	0.7	2.5	0.0	5.0	4.7	2.5	0.0	3.3	1.8	2.6	0.2	2.5	0.0	2.9	0.6
9.9	3.1	5.0	1.0	6.0	1.6	12.5	21.1	6.0	3.2	3.0	0.0	5.5	2.7	4.0	0.8	4.0	1.0	8.3	2.8
23.4	8.0	22.2	5.8	31.4	14.0	16.8	8.1	23.5	9.6	13.0	5.4	19.4	8.3	22.6	7.5	15.7	6.4	29.8	11.2
37.5	13.8	18.0	7.7	20.3	10.8	14.8	7.3	14.5	9.2	7.0	2.9	13.3	8.2	13.2	7.5	3.3	4.0	20.2	3.9
10.4	4.4	5.6	4.0	9.3	5.2	4.0	2.4	6.8	6.4	5.0	2.7	4.2	2.2	4.5	2.2	2.3	1.1	9.6	4.7
22.13	7.27	27.10	9.76	26.52	9.82	22.14	8.29	28.74	5.32	33.60	1.86	25.39	9.02	30.50	4.64	26.87	4.34	30.17	8.78
0.12	0.24	0.25	0.20	0.26	0.23	0.26	0.36	0.23	0.24	0.27	0.23	0.22	0.25	0.23	0.25	0.40	0.35	0.37	0.17
33.36	3.06	30.05	3.80	29.51	6.44	28.14	3.71	27.62	7.13	26.04	2.64	26.01	11.37	27.27	2.19	29.69	1.47	29.56	16.89
36.65	3.68	35.25	3.46	37.53	12.63	33.29	4.70	36.50	7.10	37.45	2.64	42.22	19.80	36.13	2.16	35.18	2.32	32.66	14.46
3.30	1.78	3.49	1.66	3.73	1.66	8.95	4.23	3.14	1.77	1.85	0.49	2.82	1.72	3.62	1.43	4.91	2.00	4.17	1.73
0.00	0.00	0.00	0.00	0.11	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.79	0.82	0.14	0.41	0.18	0.42	0.49	0.74	0.26	0.66	0.00	0.00	0.65	1.69	0.19	0.34	0.00	0.00	0.01	0.66
1.41	1.11	0.82	0.56	0.92	0.69	3.77	2.10	0.75	0.87	0.16	0.06	0.81	0.77	0.96	1.45	1.60	0.87	1.64	0.40
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.36	0.59	0.85	0.54	0.79	0.38	1.76	0.90	2.09	7.19	0.30	0.25	0.35	0.39	0.66	0.40	0.87	0.91	0.97	0.12
0.58	0.34	0.28	0.28	0.31	0.14	0.85	0.38	0.27	0.27	0.08	0.01	0.28	0.24	0.23	0.14	0.34	0.17	0.34	0.20

KEY TO UNITS (MHIS–Monkey Hill Intrusive Suite)

10 (MBIS) Syenite, Quartz Syenite, Granite
11 Witchdoctor granite
12 Burnt Lake granite
13 Otter Lake–Walker Lake granite
14 (MHIS) Monkey Hill Granite
15 (MHIS) Round Pond granite
16 (MHIS) Duck Island granite
17 (MHIS) Little Monkey Hill granite
18 (MHIS) Bent's Cove granite
19 (MHIS) Kidlaluit granite
n^1 Number of analyses for all elements except those listed below
n^2 Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf



KEY TO ROCK TYPES

GBBR – Gabbro
DORT – Diorite
QZDR – Quartz diorite
QZMD – Quartz monzodiorite
MNZN – Monzonite
SENT – Syenite
AFST – Alkali feldspar syenite
QZMZ – Quartz monzonite
QZST – Quartz syenite
AQST – Alkali feldspar quartz syenite
TNLT – Tonalite
GRDR – Granodiorite
MZGT – Monzogranite
GRNT – Granite (*ss*)
AFGT – Alkali feldspar granite

Figure 26. *Relative abundance of IUGS rock types amongst Labradorian plutonic rocks, calculated from normative mineralogy using the method of Streckeisen and LeMaitre (1979). Note that this is based on Barth mesonorms, not the CIPW norms listed in tables. Regional and geological sample populations.*

stratigraphically higher parts of the intrusion. It must be stressed, once again, that the complexity of this body precludes any unequivocal interpretation of its structure and anatomy. However, bearing in mind the field evidence for multiple batches of mafic magma, it is felt that these geochemical and spatial variations point to the existence of discrete magma sequences at Adlavik Bay.

Major-Element Patterns

Major-element variation (Figure 29) is assessed using MgO as a differentiation index, rather than SiO_2. The clearest distinction between gabbronorite and gabbro sequences is shown by TiO_2, which is strongly enriched in the latter below 10 percent MgO. The gabbronorite sequence has convex-upward CaO and FeO trends, and lower CaO and FeO^t than the gabbro sequence above 10 percent MgO. It also shows higher SiO_2 and K_2O (see also Table 7), but there is considerable overlap between the two. Samples from fine-grained marginal rocks have varied compositions, and clearly do not represent any one homogeneous 'parental' composition unmodified by differentiation.

Trace-Element Patterns

Trace elements (Figure 30) show entirely predictable trends for mafic magmas, and there are few systematic differences between gabbronorite and gabbro sequences.

Compatible trace elements (e.g., Cr, V, Cu) are positively correlated with MgO. High Cu contents characterize parts of the gabbro sequence. V shows minimal variation from 30 to 5 percent MgO, and possibly increases slightly down to this point. It is, however, depleted very rapidly below 5 percent MgO, and in the diorite unit.

LFS and HFS trace elements, and REE, increase with decreasing MgO, and, except for Sr, are invariably highest in the diorite unit. Sr enrichment is most apparent in the gabbro sequence, reflecting the presence of plagioclase cumulates. Ba behaves incompatibly throughout differentiation, and is strongly enriched in some samples from the diorite unit, which locally contains over 4000 ppm Ba. All of these trace-element trends are broadly consistent with evolution by fractional crystallization of mafic minerals (olivine, pyroxenes), followed by plagioclase fractionation at later stages in the process.

Geochemistry of Labradorian Siliceous Granitoid Rocks

Labradorian siliceous granitoid rocks are divided into three groups (A, B and C) to reduce clutter in variation diagrams that follow (e.g., see Figure 31). Diagrams that use SiO_2 as the X-axis employ a wider horizontal scale for the Mount Benedict Intrusive Suite (Group A), in order to accommodate its wide variation in silica content. This Mount Benedict Intrusive Suite is almost certainly genetically related to the Adlavik Intrusive Suite as a differentiated fraction of a similar mafic parental magma, and evidence for such a link is presented below. However, it is convenient to describe it in conjunction with siliceous granitoid units.

Major-Element Patterns

Major elements (Figure 31) follow entirely predictable behaviour patterns, and all oxides except Na_2O and K_2O are negatively correlated with SiO_2. The Mount Benedict Intrusive Suite has the greatest range of major-element compositions, and the Monkey Hill Intrusive Suite the narrowest range. The Mount Benedict Intrusive Suite has smooth, well-defined trends for all major elements from the least (diorite) to most differentiated (syenite to granite) units. Some (e.g., CaO, Na_2O) are curvilinear, and show inflections at a SiO_2 content of about 62 percent. N/N+K ratio patterns indicate minor disturbance of alkali elements in some leucocratic granites of the Monkey Hill Intrusive Suite.

K+N/A (agpaitic index) patterns indicate that there are no Labradorian peralkaline rocks. A/C+N+K (alumina index) patterns indicate that the Monkey Hill Intrusive Suite and Witchdoctor–Burnt Lake granites are mostly peraluminous, and that the Otter Lake–Walker Lake granite unit is peraluminous above 70 percent SiO_2. A few high-SiO_2 rocks from the Mount Benedict Intrusive Suite are also peraluminous in composition.

Normative Compositions

In the Quartz–Albite–Anorthite–Orthoclase quaternary system (Figure 32), only parts of the Mount Benedict Intrusive Suite contain > 20 percent anorthite component. All other units are anorthite-poor. In the Q–Ab–Or projection, the Mount Benedict Intrusive Suite has a well-defined trend that partly corresponds to the location of plagioclase–K-feldspar cotectic lines for high Ab/An ratios (James and Hamilton, 1969), and terminates in the ternary eutectic minimum area of the granite system. In detail, there is an inflection in this curvilinear trend that corresponds to the about 62 percent SiO_2 inflection noted above in Harker-type variation diagrams; the least evolved part of the suite lies within the plagioclase stability field. Granites of the Monkey Hill Intrusive Suite, Witchdoctor and Burnt Lake granites are also clustered around the ternary minimum, although some samples are scattered towards the albite corner (reflecting alkali-disturbance).

Trace-Element Patterns

Compatible trace elements (e.g., V, Cu, Cr, Ni and Sc) as typified by V, all show similar, uninformative inverse trends against SiO_2 (Figures 33 and 34). High levels of these elements are observed only in the least evolved parts of the Mount Benedict Intrusive Suite.

Incompatible LFS trace elements (e.g., Rb, Th) are positively (but not strongly) correlated with SiO_2, and discriminate the Mount Benedict Intrusive Suite from all other Labradorian units. The Mount Benedict Intrusive Suite is enriched in Rb and Th (also Cs, Sn, U; not shown) at all SiO_2 levels.

Sr and Ba show generally inverse trends against SiO_2. There is an inflection in the Ba trend for the Mount Benedict Intrusive Suite at about 62 percent SiO_2; up to this point, Ba remains constant or increases slightly. The inflection point

Table 7. Average compositions of textural and mineralogical subdivisions in the main body of the Adlavik Intrusive Suite

ANALYSES	1		2		3		4		5		6	
n[1]	7		7		2		2		4		7	
n[2]	1		2		0		1				1	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	45.07	2.62	46.39	4.29	53.35	1.48	52.08	0.46	48.78	4.19	50.24	2.18
TiO_2	0.86	0.56	0.88	0.50	1.00	0.26	0.82	0.08	0.73	0.19	1.04	0.18
Al_2O_3	10.46	3.01	13.97	1.64	16.08	1.91	14.64	3.43	21.23	4.34	19.69	1.51
Fe_2O_3	4.08	1.82	4.41	3.07	3.06	0.15	2.36	0.43	3.12	1.44	3.79	0.78
FeO	6.92	1.30	6.57	2.41	5.87	1.82	7.46	1.20	4.30	1.99	5.13	0.98
MnO	0.17	0.01	0.17	0.02	0.19	0.06	0.19	0.01	0.11	0.04	0.13	0.03
MgO	17.03	8.09	8.91	1.35	5.13	1.45	8.24	4.18	4.05	2.40	3.68	1.08
CaO	8.93	2.56	13.96	2.01	7.31	0.18	7.36	0.30	10.36	2.60	9.00	1.00
Na_2O	1.88	0.71	1.89	0.94	3.58	0.77	3.32	1.23	3.49	1.26	3.68	0.24
K_2O	1.35	0.51	0.77	0.69	2.07	0.33	1.92	0.47	1.74	1.09	1.28	0.54
P_2O_5	0.49	0.79	0.09	0.10	0.39	0.25	0.22	0.04	0.37	0.27	0.80	0.46
LOI	2.62	1.64	1.49	0.45	1.56	0.37	1.06	0.98	2.01	0.80	1.13	0.62
TOTAL	99.86		99.50		99.59		99.67		100.29		99.59	
(ppm)	Trace elements											
Li	26.9	11.6	20.7	4.7	25.5	2.1	20.0	4.2	33.5	23.6	20.4	3.7
F	638.3	324.5	305.9	325.4	804.0	189.5	765.5	27.6	600.5	484.5	1881.4	3570
Sc	25.7		48.8	0.8			23.0				19.0	
V	232.7	158.7	323.9	243.4	216.0	33.9	167.0	15.6	213.5	190.9	201.7	64.4
Cr	1014.0	665.7	140.1	193.7	96.5	123.7	113.0	62.2	78.3	127.9	24.3	19.7
Ni	348.4	277.7	45.1	27.6	26.5	29.0	55.0	19.8	19.0	17.5	13.3	11.2
Cu	52.9	39.2	88.6	49.6	63.5	30.4	28.5	2.1	37.0	29.4	26.4	9.9
Zn	94.6	32.3	100.6	40.7	132.0	41.0	168.5	94.1	71.3	29.9	98.3	16.0
Ga	19.0	8.2	21.6	10.6	19.5	0.7	18.0	7.1	21.3	2.2	25.1	3.3
Rb	41.6	49.9	18.6	7.9	71.0	19.8	61.5	16.3	64.0	45.0	28.4	15.1
Sr	495.6	231.2	730.4	114.9	682.5	202.9	516.0	63.6	1030.5	122.1	981.4	93.0
Y	13.4	11.1	15.3	4.3	25.0	9.9	24.0	2.8	13.3	5.3	20.6	6.4
Zr	38.6	7.7	39.6	20.2	116.0	32.5	104.0	15.6	53.0	52.0	65.4	43.0
Nb	2.9	2.0	1.4	1.7	3.5	0.7	1.0	1.4	5.3	6.7	2.3	2.9
Mo	2.9	0.9	3.9	2.8	3.5	0.7	3.5	0.7	3.8	0.5	3.6	0.5
Sn	1.0		1.0	0.0			1.0				1.0	
Cs	7.0		0.5	0.0			0.9				0.5	
Ba	419.7	98.8	281.7	144.6	831.0	267.3	578.5	161.9	594.8	293.8	647.9	195.6
La	18.4	17.3	8.6	7.5	30.5	10.6	26.5	6.4	22.8	14.4	25.9	9.4
Ce	42.0	45.2	30.7	11.9	58.5	10.6	46.5	7.8	45.8	33.4	57.4	21.5
Sm	3.5		4.4	0.4			5.0				5.6	
Yb	2.5		2.5	0.0			2.5				2.5	
Hf	1.0		1.0	0.0			3.1				3.0	
Pb	2.0	1.7	1.7	1.3	18.5	17.7	11.0	11.3	3.5	3.1	4.1	3.3
Th	2.6	1.5	1.4	1.1	1.0	0.0	1.0	0.0	5.4	4.8	4.2	3.1
U	0.6	0.3	0.5	0.4	2.7	0.9	0.8	0.3	1.3	1.7	0.8	0.4
(Wt%)	CIPW norms (partial)											
Q	0.00	0.00	0.00	0.00	1.81	1.12	0.00	0.00	0.00	0.00	0.98	1.26
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.25	0.24	0.64
Or	8.20	3.08	4.65	4.13	12.47	1.92	11.46	2.74	10.44	6.47	7.67	3.32
Ab	13.59	6.00	13.63	7.09	30.82	6.55	28.52	10.80	25.36	9.60	31.54	2.03
An	16.46	6.43	27.88	7.79	22.13	0.74	19.66	5.48	37.45	15.96	33.25	5.69
Ne	1.47	2.01	1.44	1.64	0.00	0.00	0.00	0.00	2.53	1.41	0.00	0.00
Di	20.47	6.65	33.88	6.95	10.26	0.13	13.14	2.66	10.14	11.34	5.00	3.24
Hy	1.89	2.57	0.17	0.33	15.11	6.60	12.09	11.56	0.00	0.00	11.15	3.38
Ol	28.75	15.59	9.83	4.15	0.00	0.00	9.55	0.08	6.98	2.37	0.45	1.09
Mt	6.08	2.73	6.52	4.56	4.51	0.23	3.46	0.67	4.59	2.12	5.58	1.14
Il	1.67	1.07	1.70	0.98	1.93	0.51	1.58	0.18	1.40	0.37	2.00	0.35

KEY TO ANALYSES

1 Ultramafic Rocks
2 Mafic cumulate facies (Cpx ± Ol)
3 Mafic cumulate facies (Cpx + Opx)
4 Mafic cumulate facies (Cpx + Opx + Ol)
5 Melanocratic gabbro facies
6 Melanocratic gabbro facies
n[1] Number of analyses for all elements except those below
n[2] Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 7. *(Continued)*

7		8		9		10		11	
26		8		10		14		7	
5		0		2		2		1	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
47.64	2.86	54.07	2.17	51.49	1.69	57.90	3.01	53.42	5.46
1.01	0.55	0.86	0.20	0.81	0.18	0.81	0.30	1.16	0.72
14.59	3.93	18.88	2.76	16.36	3.89	17.85	1.28	15.07	2.46
2.88	1.35	2.41	0.75	2.38	0.56	1.94	0.72	2.98	1.42
6.98	1.56	4.88	1.47	6.09	0.81	4.01	1.45	6.04	2.14
0.18	0.04	0.13	0.04	0.15	0.04	0.13	0.03	0.17	0.03
9.22	4.68	3.62	1.46	7.45	4.94	2.46	1.55	6.07	3.54
11.57	2.80	7.50	1.48	8.82	1.30	4.83	1.92	7.31	2.60
2.59	1.29	4.20	0.46	3.40	1.09	5.27	1.02	3.60	1.07
0.99	0.70	1.86	0.62	1.44	0.57	3.31	0.93	2.28	0.86
0.30	0.37	0.27	0.08	0.17	0.10	0.31	0.15	0.41	0.40
1.49	0.51	0.77	0.39	0.97	0.36	0.77	0.34	1.21	0.39
99.44		99.45		99.53		99.59		99.72	
17.8	7.3	20.4	5.5	20.3	4.8	19.2	7.0	26.0	8.1
516.2	404.1	547.8	196.6	583.7	452.0	840.2	394.4	1286.0	896.0
43.0	19.0			21.9	6.9	15.0	0.0	20.0	
202.6	82.3	156.3	57.0	185.6	35.0	91.8	68.0	171.0	60.4
345.2	440.8	47.3	36.5	365.8	563.4	29.4	33.1	234.9	253.8
83.3	85.2	16.8	9.1	88.1	104.5	10.9	11.3	58.1	44.3
72.3	49.1	22.8	15.9	41.2	28.6	23.0	16.2	33.0	24.0
87.9	44.6	88.0	22.6	88.6	20.8	77.4	18.8	129.1	51.2
18.5	6.1	22.4	2.7	20.2	3.1	16.6	5.1	22.3	6.1
28.0	22.1	49.1	19.1	41.4	19.9	75.8	23.2	64.1	29.1
774.6	381.5	927.5	202.3	708.1	295.3	711.8	202.7	610.1	243.3
17.8	10.3	18.1	4.6	16.8	5.5	20.7	4.6	37.3	17.2
52.3	43.0	83.4	39.4	69.4	47.0	95.9	50.6	179.0	102.8
2.3	3.1	5.1	2.9	3.7	3.1	10.0	3.4	8.9	6.4
3.0	0.5	3.8	0.5	3.6	1.7	2.9	0.8	3.6	0.8
1.0	0.0			1.0	0.0	1.0	0.0	1.0	
0.5	0.0			0.5	0.0	1.3	1.1	2.0	
542.2	455.0	776.4	215.4	593.4	276.9	1554.1	1251	824.0	483.5
17.5	13.9	27.5	7.0	20.8	11.0	33.4	8.2	38.3	16.5
40.3	31.3	51.1	14.1	39.3	18.8	58.6	20.7	81.6	34.9
4.5	2.5			7.0	1.5	6.5	0.5	6.2	
2.5	0.0			2.5	0.0	2.5	0.0	2.5	
1.5	0.9			2.0	1.4	3.0	0.0	5.0	
2.5	3.4	5.8	3.5	9.3	14.0	9.7	4.6	8.9	5.7
1.3	0.9	1.7	2.6	0.8	0.3	3.0	3.3	5.2	4.5
0.5	0.5	1.5	1.0	0.9	0.6	2.0	1.3	1.9	1.1
0.36	1.83	1.13	1.07	0.00	0.00	1.31	1.64	2.19	4.02
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.94	4.23	11.09	3.72	8.62	3.45	19.79	5.61	13.63	5.06
19.29	10.55	35.94	3.99	29.08	9.30	44.86	8.61	30.82	9.13
25.76	7.97	27.56	8.91	25.46	6.67	15.42	5.94	18.51	5.92
1.65	1.29	0.00	0.00	0.00	0.00	0.12	0.33	0.00	0.00
24.95	13.43	7.05	3.78	14.57	8.25	5.84	4.05	12.59	10.01
0.40	2.01	10.84	4.18	8.07	3.07	6.06	4.82	9.64	4.21
14.59	7.34	0.49	1.34	8.64	6.09	1.45	2.58	4.90	4.63
4.26	2.02	3.54	1.10	3.49	0.82	2.85	1.06	4.39	2.12
1.97	1.07	1.65	0.38	1.56	0.34	1.55	0.58	2.23	1.41

KEY TO ANALYSES

7 Plagioclase cumulate facies (Cpx ± Ol)
8 Plagioclase cumulate facies (Cpx + Opx)
9 Plagioclase cumulate facies (Cpx + Opx + Ol)
10 Diorite unit
11 Marginal gabbro
n^1 Number of analyses for all elements except those below
n^2 Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

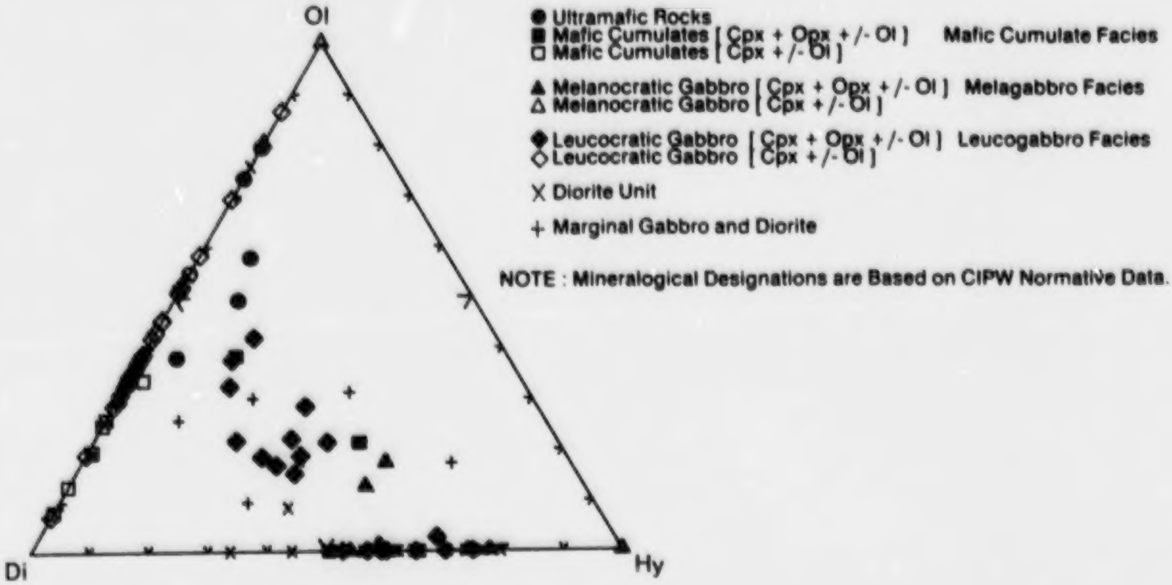


Figure 27. *Normative olivine–diopside–hypersthene projection, showing the division of the Adlavik Intrusive Suite into hypersthene-normative and hypersthene-free components.*

corresponds to the previously noted inflections defined by major element and normative variations. The Monkey Hill Intrusive Suite and similar granites show rapid depletion of Ba with increasing SiO_2.

HFS trace elements such as Zr and Nb have convex-upward trends with inflection points at about 67 percent SiO_2 in the Mount Benedict Intrusive Suite. At higher SiO_2 contents, both elements are rapidly depleted. High Zr in the 60 to 67 percent SiO_2 range distinguishes the Mount Benedict Intrusive Suite from other Labradorian units, which mostly contain less than 300 ppm Zr, and have constant or decreasing Zr with increasing SiO_2.

Y and Ce trends are subhorizontal in the Mount Benedict Intrusive Suite, but both elements are depleted above 67 percent SiO_2. It is also enriched in fluorine relative to all other Labradorian units (except parts of the Adlavik Intrusive Suite; Table 4). The convex-upward F–SiO_2 trend in the Mount Benedict Intrusive Suite is remarkably similar to the Zr, Y and Ce trends, and shows the same inflection at about 67 percent SiO_2.

The Monkey Hill Intrusive Suite plutons have generally consistent compositions, with the exception of the Round Pond granite, which displays severe depletion of Zn, Sr, Y, Zr, Ba, La, Ce, Pb and Th. This feature was noted by MacDougall (1988) in a study of mineralization in the Round Pond area, and was attributed by him to hydrothermal processes associated with metallogenesis.

Geochemical Trends in the Mount Benedict Intrusive Suite, and their Significance

The Mount Benedict Intrusive Suite is characterized by well-developed and striking geochemical trends. These trends are readily interpreted in terms of fractional crystallization, and provide constraints for a numerical modelling exercise conducted by Kerr (1989a).

Rb–Sr and Ba–Sr trends (Figure 35) provide a method of assessing the role of various common silicates in fractional crystallization, as perfect Rayleigh fractionation (i.e., where the crystals are separated from the liquid in tiny increments) will produce distinct linear trends in log-log plots; the attitudes of these trends are characteristic of specific phases. Trends in the Mount Benedict Intrusive Suite indicate that plagioclase, K-feldspar and mafic minerals were the dominant liquidus phases, which is consistent with the observed phenocryst assemblages. Plagioclase phenocrysts occur in all but the most evolved rocks, and accumulated in the diorite unit. Initial strong Rb enrichment is characteristic of plagioclase (± mafic mineral) fractionation, as is the antithetic behaviour of Ba and Sr. Both features predominate below 62 percent SiO_2 (see also Figure 31). The inflection of Ba trends at this point probably indicates the onset of K-feldspar crystallization; constant Ba/Sr during subsequent evolution suggests that both feldspars continued to crystallize in roughly constant proportions (assuming that the distribution coefficients remained constant). The inflection at about 62 percent SiO_2 also marks the point at which the evolving liquid reached the plagioclase–alkali-feldspar cotectic line (Figure 32).

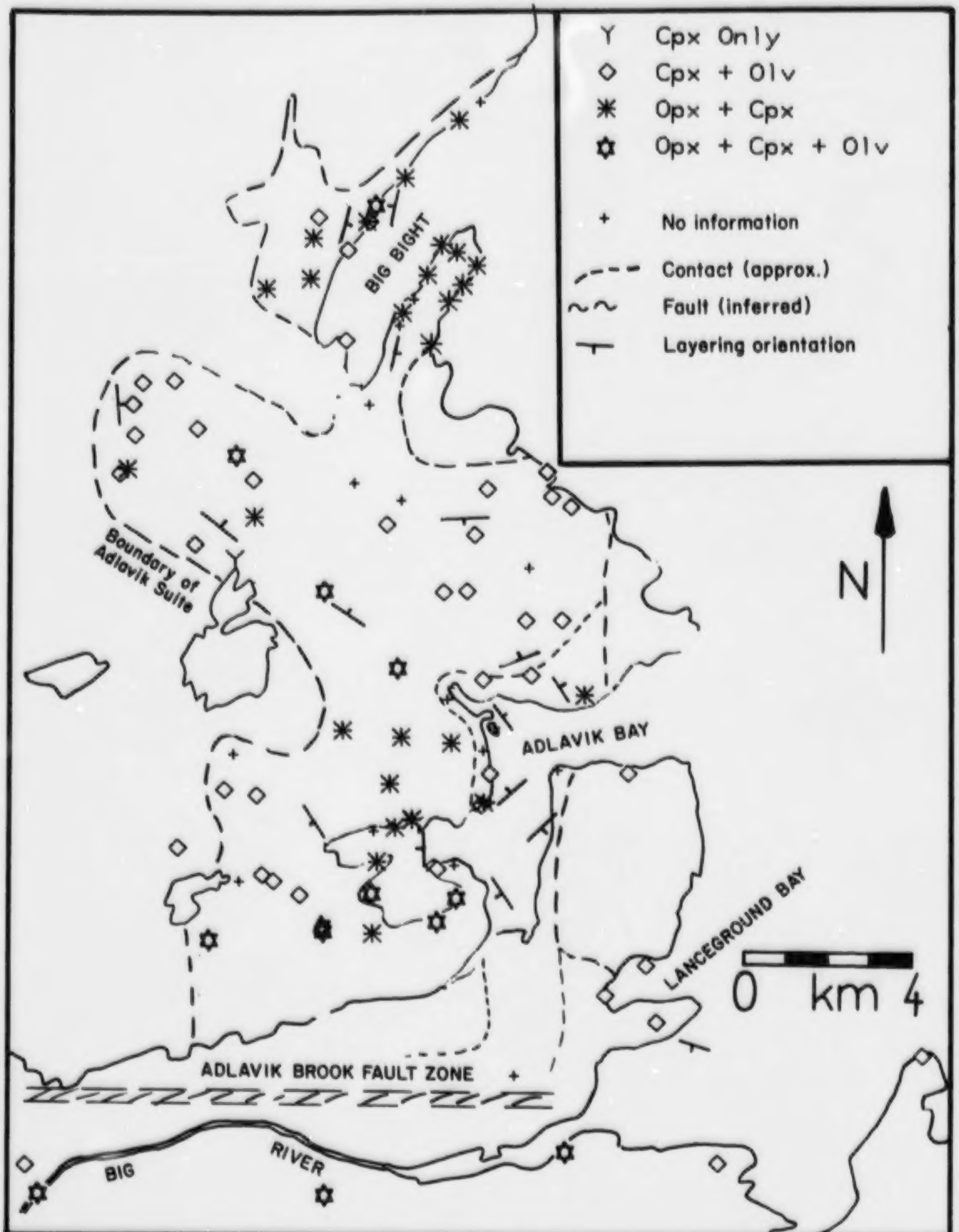


Figure 28. *Spatial variation of normative mineralogy in the main body of the Adlavik Intrusive Suite, illustrating distribution of gabbronorite and gabbro sequences.*

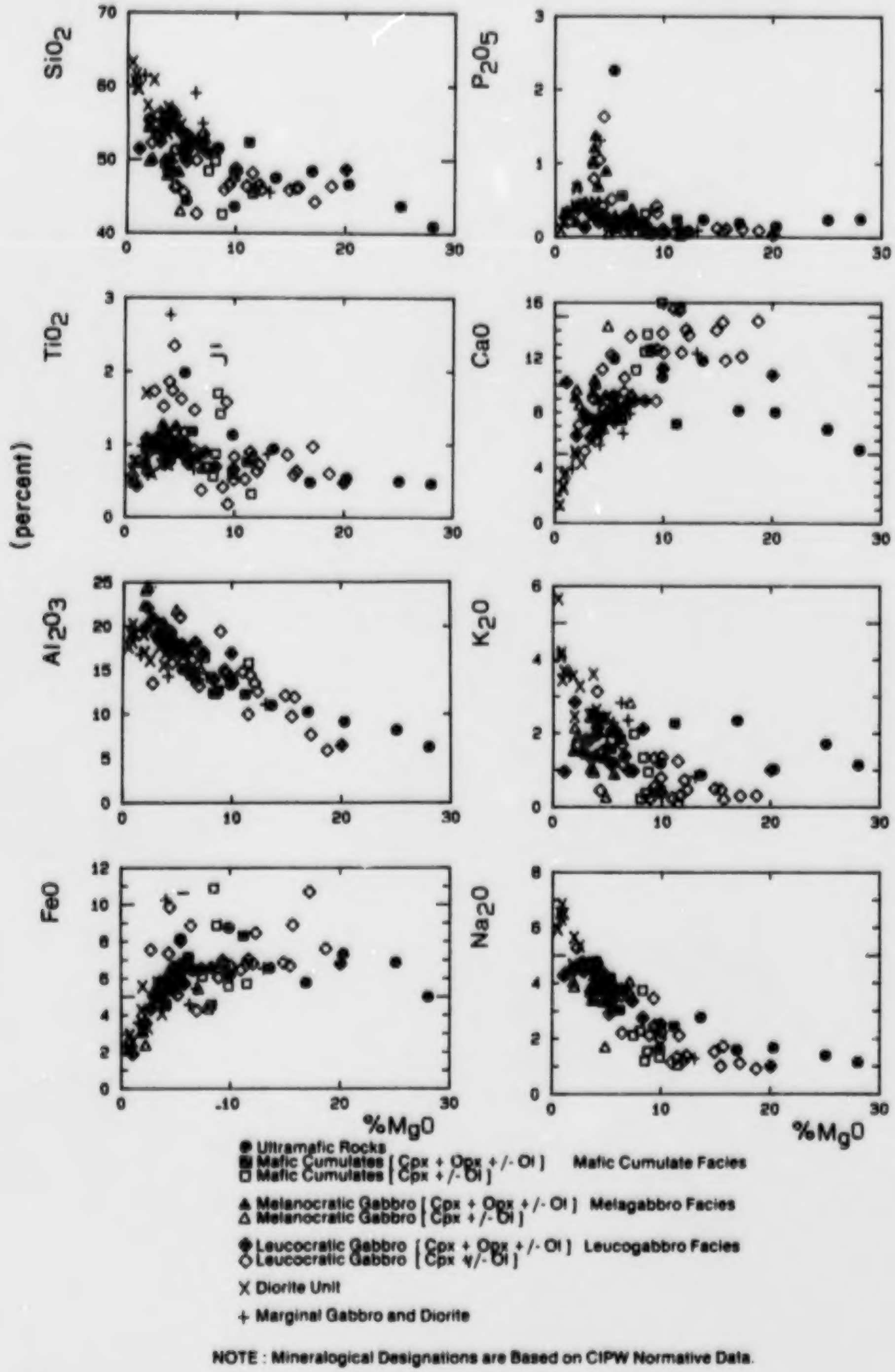


Figure 29. *Variation of selected major elements and derived ratios against MgO in the main body of the Adlavik Intrusive Suite.*

The convex-upward Zr–SiO_2 trend (Figure 34) defines the appearance of a Zr-rich phase (probably zircon) at about 67 percent SiO_2. The generally flat REE and Y trends indicate that these elements were buffered at an earlier stage, probably by accessory phases such as sphene, which locally cores hornblende. Depletion in Th and REE at the highest SiO_2 contents may indicate the effects of allanite fractionation (cf. Michael, 1983; Miller and Mittlefehldt, 1982).

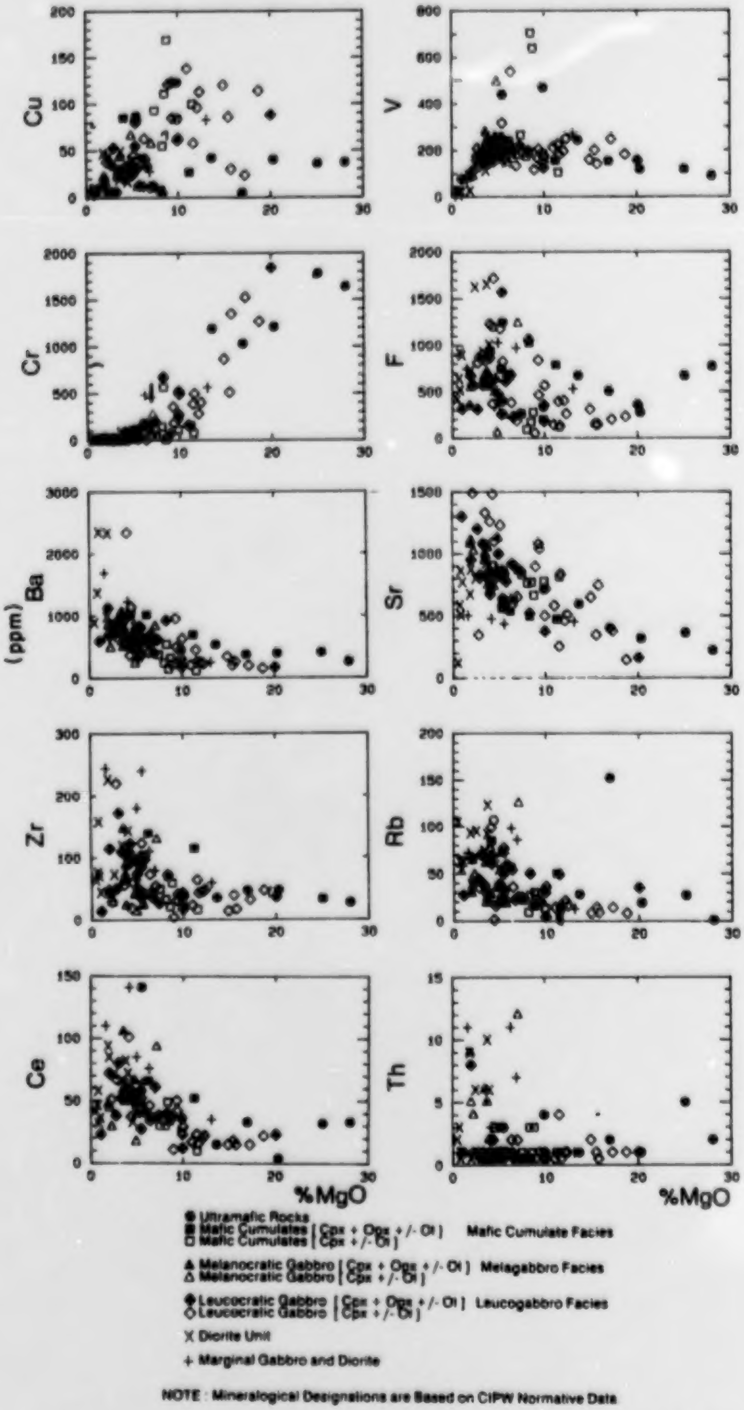


Figure 30. *Variation of selected trace elements against MgO in the main body of the Adlavik Intrusive Suite.*

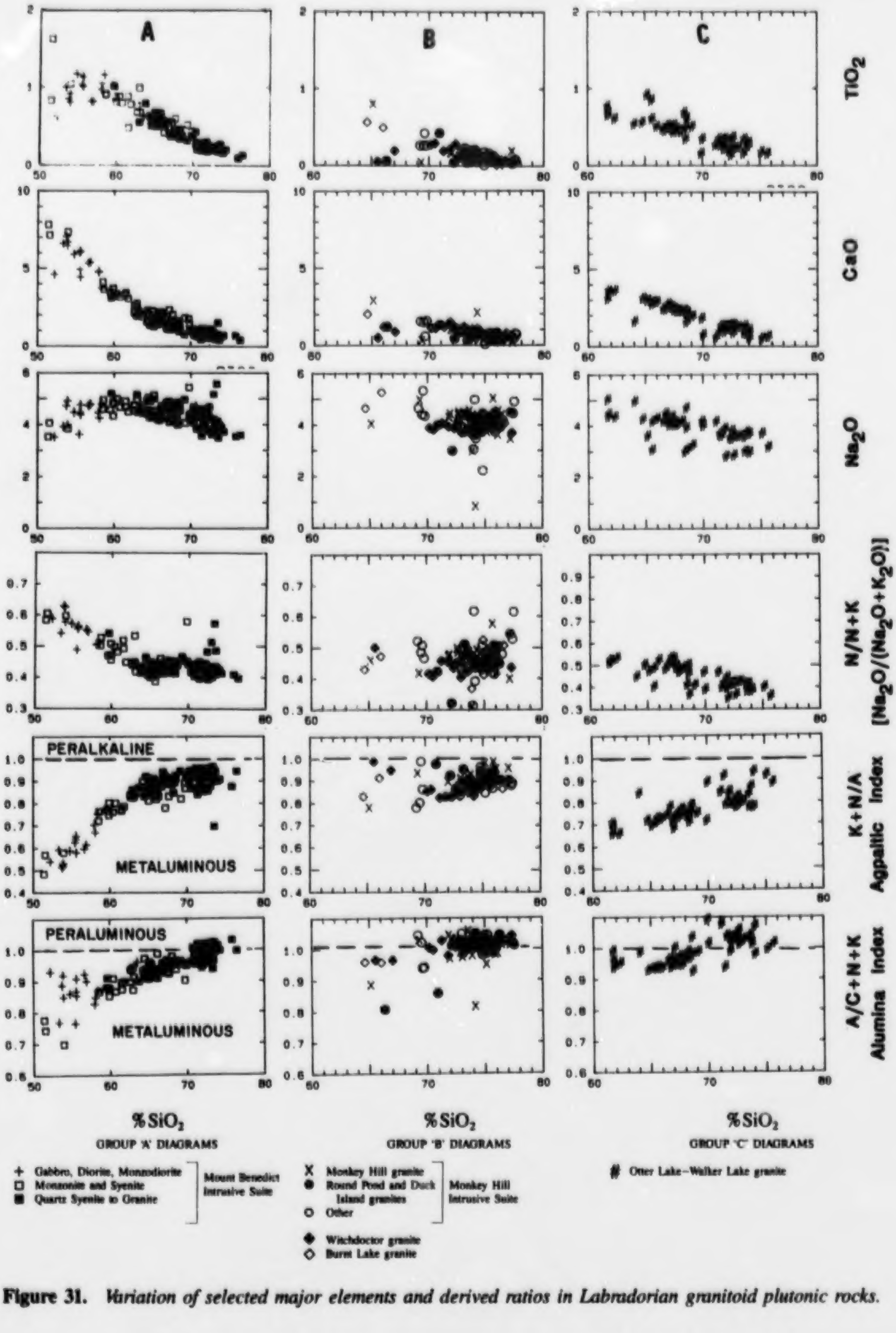


Figure 31. *Variation of selected major elements and derived ratios in Labradorian granitoid plutonic rocks.*

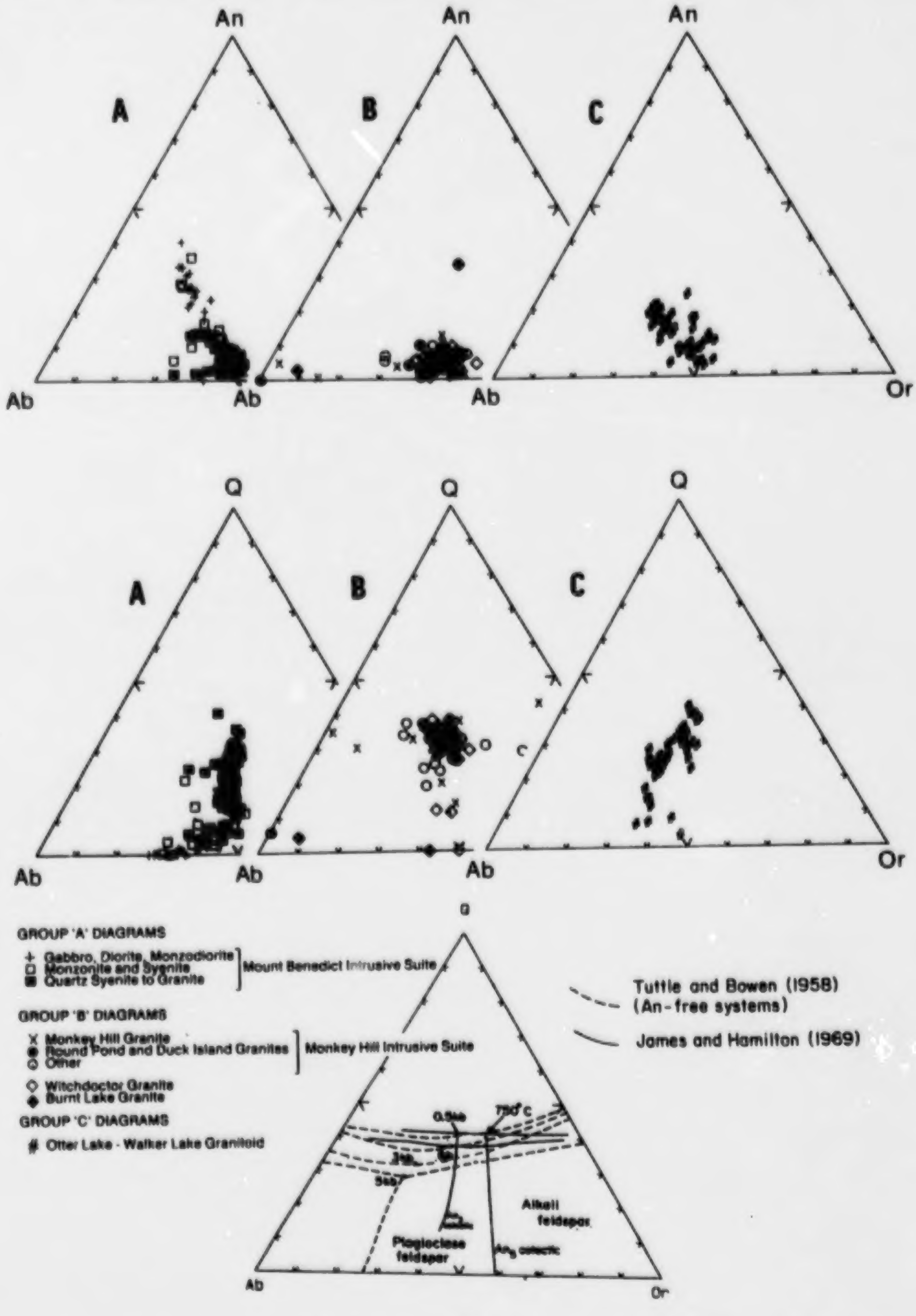


Figure 32. *Variation of Labradorian granitoid plutonic rocks in the quartz–albite–anorthite–orthoclase quaternary system. All norms are CIPW.*

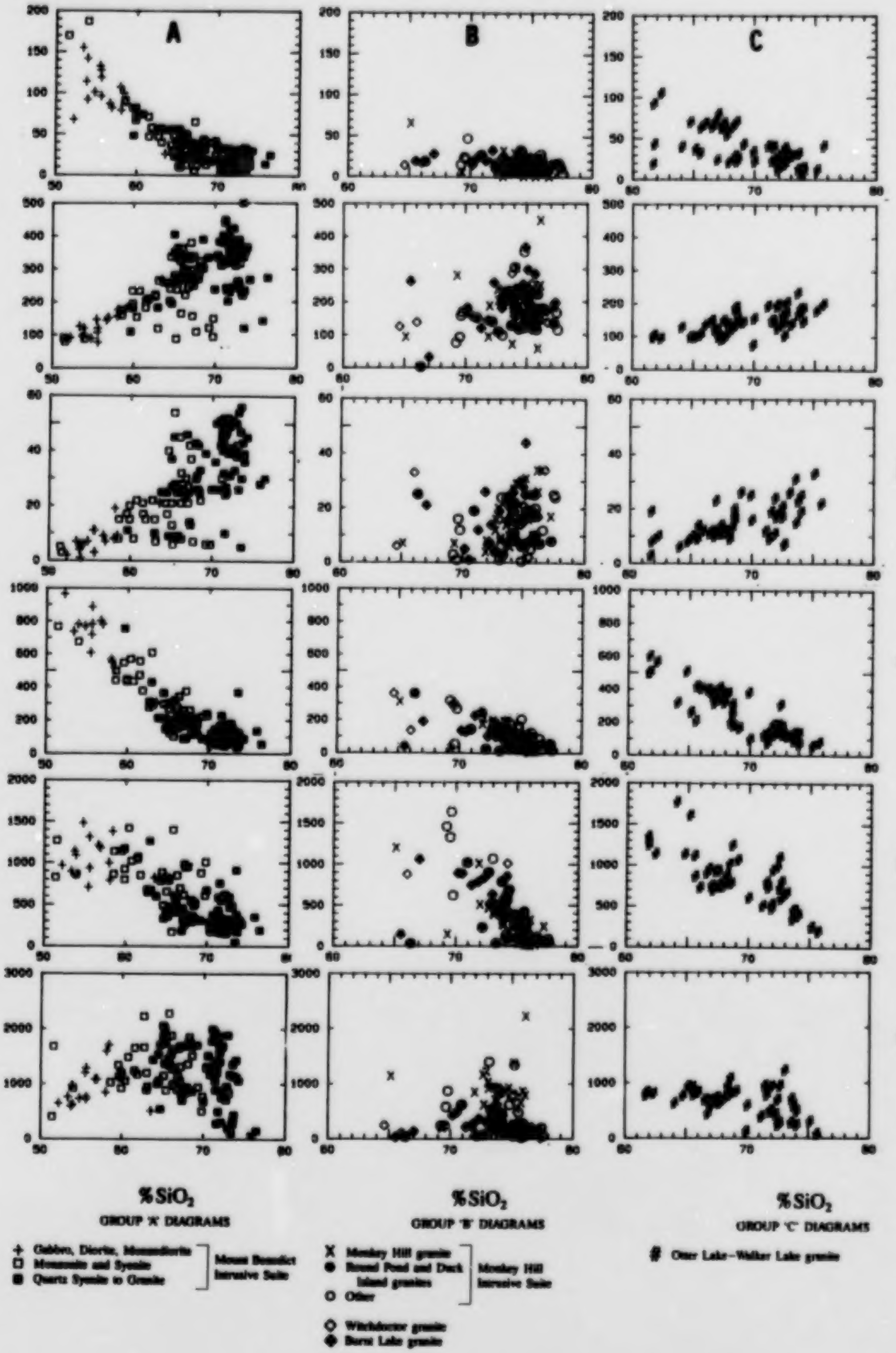


Figure 33. *V, Rb, Th, Sr, Ba and F vs SiO_2 for Labradorian granitoid plutonic rocks.*

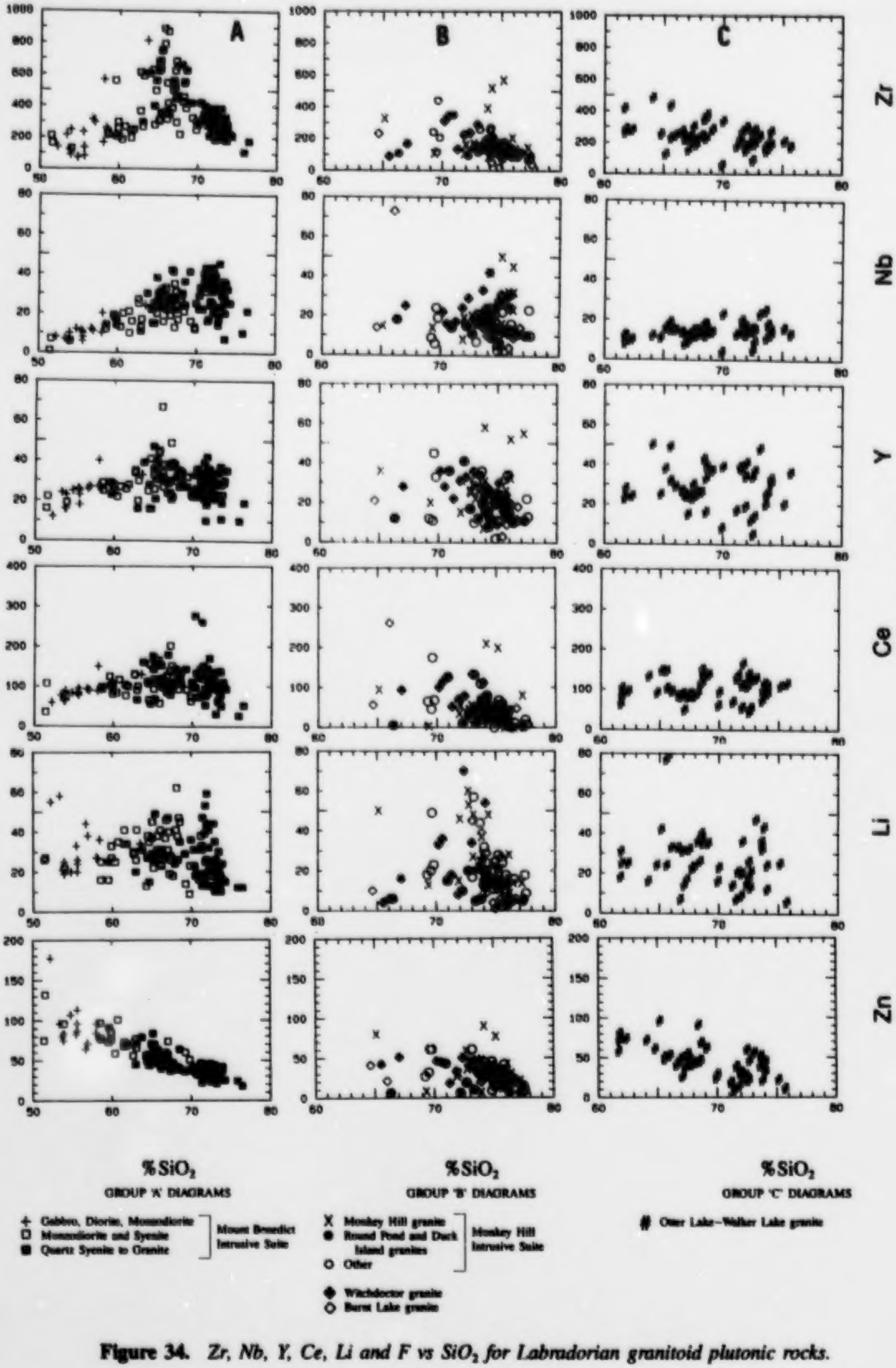


Figure 34. *Zr, Nb, Y, Ce, Li and F vs SiO_2 for Labradorian granitoid plutonic rocks.*

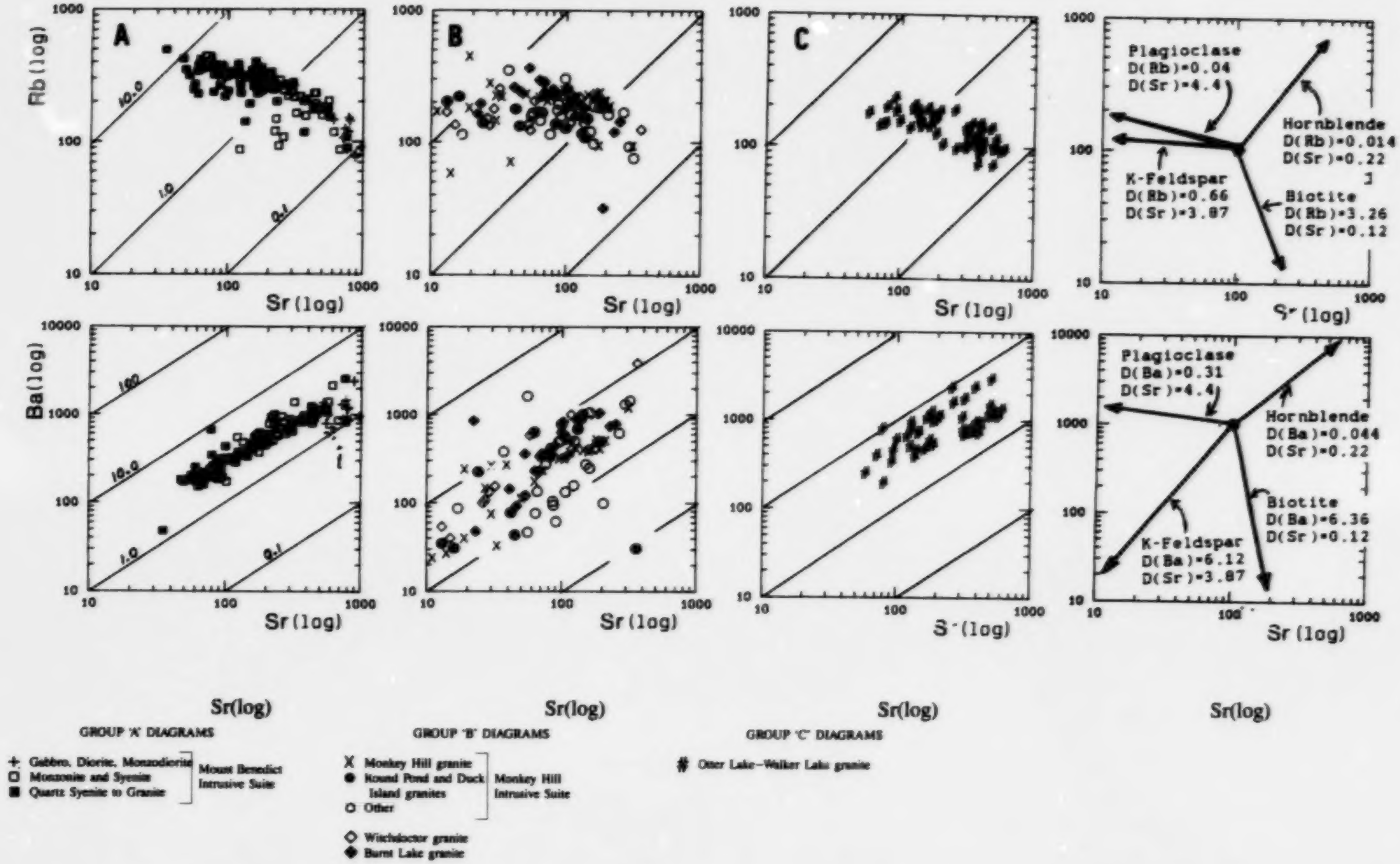


Figure 35. *Variation in the trace-element ratios Rb/Sr and Ba/Sr in Labradorian granitoid plutonic rocks. Reference fractional crystallization trends calculated from partition coefficients quoted by Arth (1976) and Hanson (1978).*

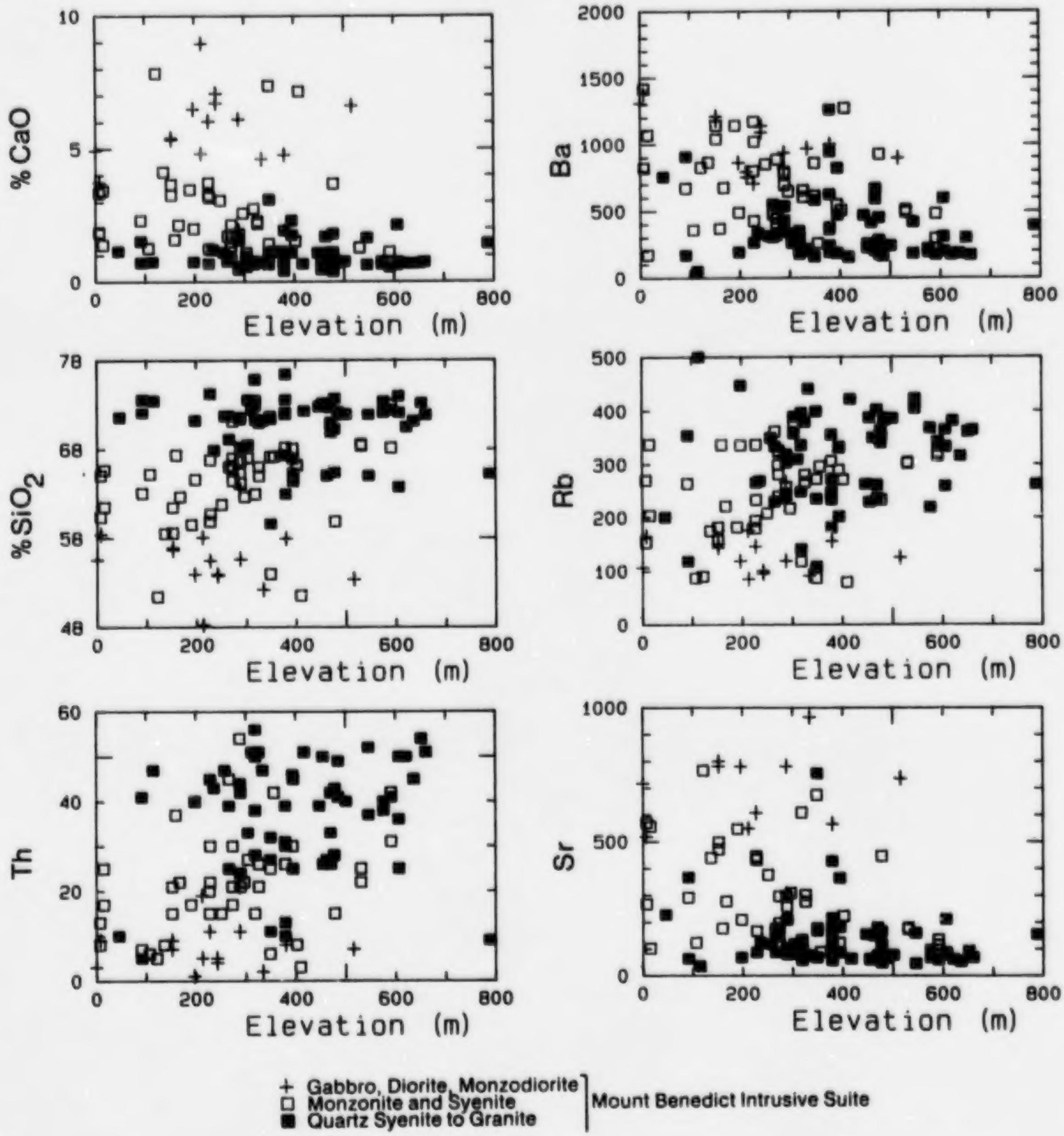


Figure 36. *Variation of selected major and trace elements against elevation (metres above sea level) in the Mount Benedict Intrusive Suite, illustrating the dominance of evolved compositions at high elevations.*

Relationship between the Adlavik and Mount Benedict Intrusive Suites

The Adlavik and Mount Benedict Intrusive suites are interpreted as complementary associations, i.e., the mafic and plagioclase cumulates of the Adlavik Intrusive Suite represent the material removed from a mafic parental magma to produce the more evolved syenitic to granitic rocks of the Mount Benedict Intrusive Suite. The diorite unit in the Mount Benedict Intrusive Suite includes plagioclase cumulates that resemble leucogabbro and diorite of the Adlavik Intrusive Suite in many respects. Their presence at the margins of and low topographic elevations within the suite suggests a crude layering or zonation, and suggests that mafic rocks may occur below the present level of exposure. The mafic rocks at Pamiulik Point, although grouped for descriptive purposes with the Adlavik Intrusive Suite, possibly represent some of this material.

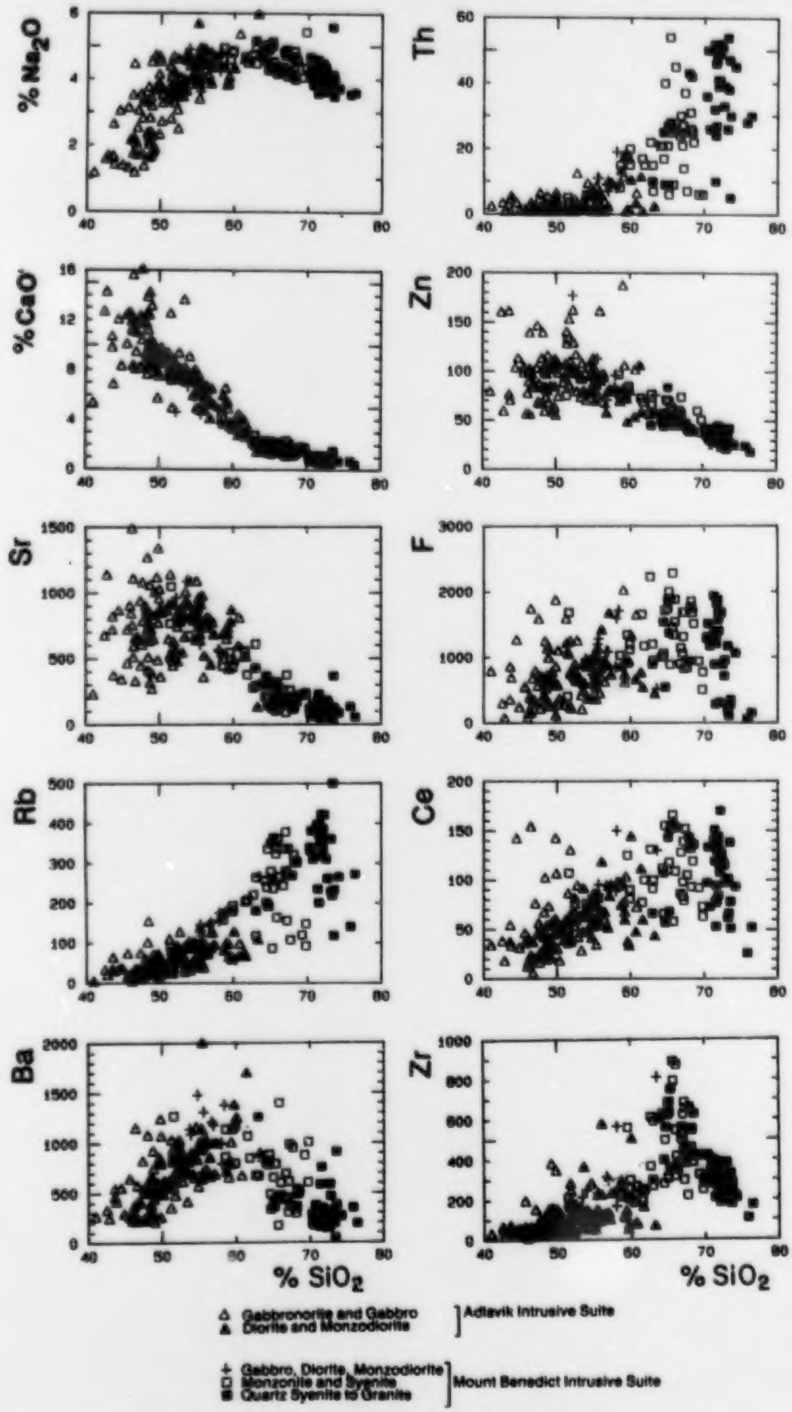


Figure 37. *Variation of selected major and trace elements against SiO_2 in the Adlavik and Mount Benedict Intrusive suites, illustrating their geochemical continuity and overlap.*

There are several indications that the Mount Benedict Intrusive Suite is also a crudely layered body. In the field, this is suggested by the preferred occurrence of the most evolved syenite and granite at high elevations, noted also by Gower (1981). Compositional layering or zonation is also indicated by geochemical variation with elevation (Figure 36).

Correlations between geochemistry and elevation are not perfect (r is generally < 0.5), but the most evolved compositions are certainly dominant at higher altitudes.

The Adlavik and Mount Benedict Intrusive suites also define smooth and continous geochemical trends against SiO_2 (Figure 37), with some scatter at low SiO_2 values that reflects the presence of cumulate rocks. The strong incompatible element enrichment in the evolved rocks of the Mount Benedict Intrusive Suite is consistent with extended fractionation of a mafic parent magma, for which the most logical candidate is the contemporaneous Adlavik Intrusive Suite.

Kerr (1989a) developed a numerical model for derivation of the Mount Benedict Intrusive Suite by progressive fractionation of an Adlavik-type parental mafic magma. The parental magma composition was assumed to be represented by the mean composition of Adlavik Intrusive Suite gabbro in the east of the area, which approximates an average basalt. Crystallization involved an initial pyroxene–olivine assemblage, with progressive involvement of plagioclase, and finally K-feldspar. The areally dominant syenomonzonite unit of the Mount Benedict Intrusive Suite could be approximated by roughly 70 percent crystallization, with the most evolved rocks corresponding to a residual liquid representing 5 to 10 percent of the original magma. Minor amounts of accessory phases are required to produce observed HFS trace-element trends. In such a model, the cumulates that are removed are represented by the Adlavik Intrusive Suite.

This model is undoubtedly simplistic, as it is a closed-system interpretation, whereas field evidence suggests multiple magma batches in the Adlavik Intrusive Suite. However, it demonstrates the feasibility of an Adlavik–Mount Benedict genetic link. As noted by O'Hara (1977), one of the most likely consequences of open-system fractionation is to produce greater enrichment of incompatible elements, thus decreasing the amount of crystallization required to generate the observed patterns from a mafic parental magma.

UNCLASSIFIED PLUTONIC ROCKS

Unclassified plutonic rocks are represented by 221 samples, of which 211 are regional samples collected on a 2-km-grid spacing. Over 60 percent of this population represents the granitoid gneiss unit that underlies most of the area south of the Benedict fault zone. Note that the Freshsteak granitoid has now been identified as a posttectonic Makkovikian intrusion using Rb–Sr geochronology (Kerr, 1989a; Kerr and Krogh, 1990). The closely similar Noarse Lake granitoid is probably a displaced portion of the same pluton. Similarly, preliminary U–Pb zircon data from the Stag Bay granodiorite (Kerr *et al.*, 1992) indicates a Makkovikian age. These units have, however, been retained as part of this chapter for descriptive purposes, and for compatibility with geochemical variation diagrams.

General Geochemistry

Summary of Numerical Data

Table 8 lists mean compositions of unclassified plutonic units, and also mean compositions of selected Makkovikian and Labradorian plutonic units that have similar SiO_2 contents.

Mean compositions of the Freshsteak and Noarse Lake units are closely similar, supporting their interpretation as disrupted components of an originally continous pluton. However, the Noarse Lake unit has a lower mean silica content, and a slightly less evolved trace-element pattern. Both units are similar in composition to the syntectonic Makkovikian Long Island Quartz Monzonite, which they physically resemble also. The Thunder Mountain syenite has a similar SiO_2 content to these rocks, but is poorer in TiO_2 and P_2O_5.

The Stag Bay and Jeanette Bay units have similar SiO_2 contents (about 68 percent), but are otherwise dissimilar. The latter is richer in K_2O and Rb, and depleted in Sr relative to Stag Bay. However, the Jeanette Bay unit has lower levels of Rb, U, and Th than rocks of comparable SiO_2 content in the Mount Benedict Intrusive Suite. Note that the high Cu content of the Stag Bay unit is a function of a single anomalous sample that has over 600 ppm Cu, and is not representative of the unit as a whole.

The mean major-element composition of the granitoid gneiss unit south of the Benedict fault zone is similar to means for either Makkovikian and Labradorian plutonic assemblages. In view of the varied lithology, this average cannot be considered representative of this composite unit.

Abundance and Distribution of Rock Types

Relative proportions of IUGS rock types were calculated from normative data after Streckeisen and LeMaitre (1979), and are shown in Figure 38.

The Freshsteak and Noarse Lake units are generally similar, but the Noarse Lake unit contains a higher proportion of diorite and monzodiorite. The Stag Bay unit is dominated by monzogranite with subordinate granite, and the Jeanette Bay unit by granite, rather than quartz syenite. The Thunder Mountain unit is of variable composition, but is mostly quartz-poor (i.e., quartz diorite to alkali-feldspar quartz syenite).

The larger sample population for granitoid gneisses south of the Benedict fault zone has a bimodal pattern, dominated by granite to alkali-feldspar granite, but with a smaller peak at quartz monzonite to quartz syenite. This pattern resembles that shown by syn- and posttectonic Makkovikian plutonic associations.

Table 8. Average compositions of unclassified plutonic rocks, subdivided by principal units

ANALYSES	1		2		3		4		5		6	
n^1	17		10		21		12		13		146	
n^2	4		1		1		0		0		0	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	63.66	5.47	60.44	4.30	68.31	4.68	67.93	4.62	64.37	8.04	68.75	5.54
TiO_2	0.87	0.39	1.05	0.35	0.36	0.12	0.47	0.19	0.55	0.29	0.48	0.35
Al_2O_3	15.48	1.57	16.28	0.67	15.52	1.47	14.99	1.58	16.44	2.21	14.57	1.61
Fe_2O_3	2.26	0.67	2.12	0.74	1.19	0.83	1.31	0.62	1.41	0.71	1.21	0.63
FeO	3.34	1.33	4.46	1.54	1.52	0.69	1.48	0.71	2.51	1.72	2.03	1.38
MnO	0.12	0.04	0.14	0.04	0.06	0.02	0.06	0.02	0.09	0.05	0.07	0.04
MgO	1.37	0.91	1.88	0.99	0.77	0.52	0.64	0.33	1.86	3.16	0.72	0.70
CaO	3.19	1.62	3.98	1.43	2.20	1.40	1.79	0.96	3.14	2.89	1.81	1.20
Na_2O	4.29	0.41	4.44	0.34	4.51	0.43	4.18	0.42	4.49	0.95	4.14	0.50
K_2O	4.19	1.08	3.88	1.16	4.17	0.93	5.35	0.83	4.14	1.76	4.85	0.98
P_2O_5	0.30	0.20	0.32	0.10	0.12	0.08	0.12	0.06	0.15	0.09	0.15	0.14
LOI	0.58	0.26	0.53	0.28	0.80	0.32	1.00	0.55	0.46	0.17	0.55	0.20
TOTAL	99.65		99.52		99.53		99.32		99.61		99.33	
(ppm)	Trace elements											
Li	21.6	8.5	56.7	44.5	18.2	4.3	15.0	3.8	14.4	4.2	19.8	9.4
F	728.3	258.0	999.1	671.9	741.2	612.2	700.5	349.7	703.8	591.2	649.7	413.7
Sc	9.0	4.7	3.9		2.6							
V	66.9	47.0	93.2	52.6	28.3	26.8	32.7	11.5	42.9	47.8	31.2	27.4
Cr	6.9	6.7	10.1	6.6	4.1	2.4	7.5	3.5	30.3	74.6	9.2	29.6
Ni	2.5	2.5	4.1	2.3	2.4	1.7	2.3	2.2	13.6	32.2	2.7	7.5
Cu	11.7	7.2	10.8	5.0	45.9	175.0	13.3	11.3	8.9	10.1	12.9	54.5
Zn	102.9	27.5	102.8	34.6	49.3	17.2	59.8	32.0	70.3	26.8	66.2	36.7
Ga	21.5	3.1	21.9	3.6	14.1	5.6	9.5	3.4	12.9	6.9	12.3	5.8
Rb	109.1	36.7	118.3	61.8	104.7	44.8	162.9	50.6	69.5	55.7	112.6	44.7
Sr	359.9	184.7	410.4	138.2	474.5	267.3	232.8	129.0	462.0	326.8	253.4	188.7
Y	49.6	22.0	35.4	6.9	24.6	19.5	31.5	9.5	22.9	16.1	32.1	14.9
Zr	307.1	156.4	221.9	103.8	254.4	149.6	322.0	126.8	340.3	455.6	338.6	162.0
Nb	16.4	7.3	10.7	3.6	12.9	9.7	15.9	5.2	11.7	10.8	15.3	7.1
Mo	4.2	1.2	4.4	1.6	3.0	1.9	5.3	5.7	3.3	1.0	3.8	2.1
Sn	2.3	1.5	1.0		2.0							
Cs	1.9	1.0	5.0		2.0							
Ba	1368.4	545.3	1906.0	685.8	987.8	406.4	819.0	189.7	1512.1	1628	907.3	637.2
La	68.5	29.4	43.5	8.0	44.9	35.8	48.6	22.5	36.2	28.6	43.8	27.4
Ce	128.4	58.8	82.9	15.4	90.1	74.8	93.6	38.7	74.9	62.2	89.6	52.4
Sm	14.0	4.1	4.3		4.6							
Yb	4.8	2.7	2.5		2.5							
Hf	11.5	3.4	5.0		13.0							
Pb	15.3	3.6	13.8	4.7	17.3	19.8	23.8	9.7	12.2	8.0	18.6	42.4
Th	5.0	5.9	2.9	2.6	10.4	17.1	13.3	7.9	4.5	8.5	7.8	7.8
U	3.2	1.6	2.8	1.0	4.3	3.4	4.0	1.1	1.5	1.9	3.6	2.6
(Wt%)	CIPW norms (partial)											
Q	14.00	8.06	8.04	6.31	19.44	8.14	19.24	9.00	13.37	11.05	20.55	10.35
C	0.00	0.00	0.00	0.00	0.21	0.26	0.03	0.06	0.10	0.20	0.08	0.16
Or	24.96	6.38	23.13	6.89	24.95	5.55	32.18	5.19	24.65	10.43	28.97	5.84
Ab	36.58	3.45	37.94	2.90	38.61	3.78	35.07	2.52	38.22	8.01	35.53	4.22
An	10.74	5.53	13.16	3.92	9.36	4.97	6.35	3.53	12.33	11.13	6.72	4.24
Di	3.04	1.64	4.28	2.44	1.02	2.17	1.50	1.73	2.32	3.10	1.41	1.62
Hy	5.03	3.06	7.62	2.80	2.58	1.28	1.90	1.44	3.56	2.13	3.21	2.76
Ol	0.00	0.00	0.00	0.00	0.15	0.70	0.00	0.00	1.95	4.96	0.02	0.19
Mt	3.31	1.00	3.11	1.07	1.75	1.20	1.89	0.87	2.07	1.05	1.76	0.93
Il	1.66	0.75	2.01	0.66	0.69	0.24	0.91	0.36	1.06	0.55	0.94	0.67

KEY TO ANALYSES:

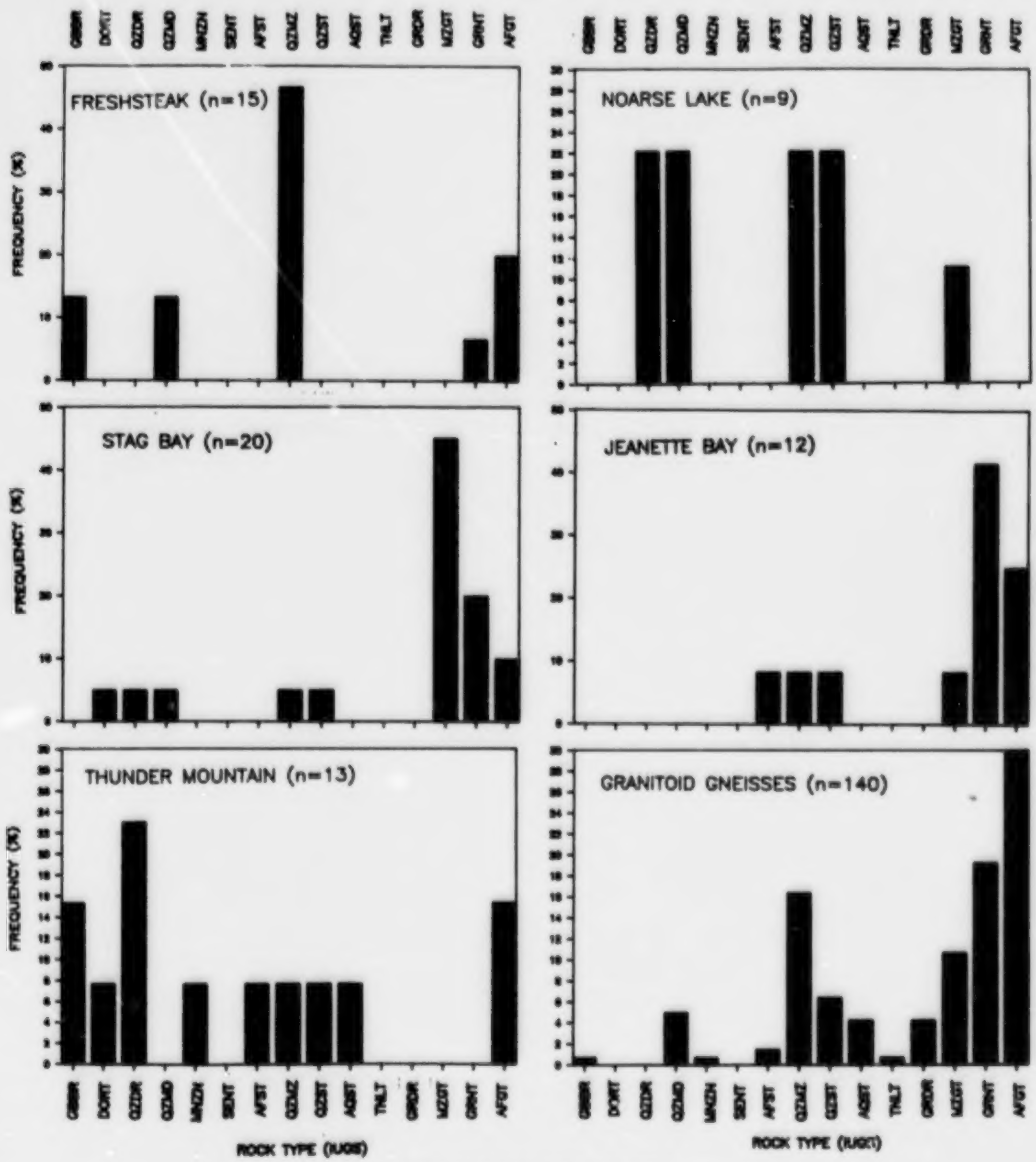
1 Freshsteak granitoid
2 Noarse Lake granitoid
3 Stag Bay granodiorite
n^1 Number of analyses for all elements except those listed below
4 Jeanette Bay quartz syenite
5 Thunder Mountain syenite
6 Granitoid Gneisses south of the Benedict fault zone
n^2 Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 8. *(Continued)*

7		8		9		10		11		12	
15		57		53		67		49		79	
5		12		22		39		11		13	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
63.32	1.27	62.31	4.27	64.46	4.46	70.69	3.31	68.54	4.42	70.11	5.15
0.88	0.06	0.78	0.29	0.61	0.24	0.30	0.18	0.44	0.20	0.39	0.22
15.81	0.24	16.69	1.49	16.03	0.93	14.39	1.06	14.98	1.62	14.43	1.74
1.79	0.37	1.72	0.75	1.40	0.66	0.97	0.40	1.20	0.61	1.16	0.55
3.06	0.73	3.41	1.12	2.53	1.12	1.09	0.66	1.87	1.01	1.49	0.97
0.10	0.01	0.12	0.05	0.09	0.03	0.05	0.02	0.06	0.03	0.06	0.04
1.25	0.42	1.22	0.87	1.12	0.97	0.38	0.27	0.86	0.54	0.50	0.84
2.95	0.48	2.92	1.30	2.37	1.52	0.97	0.49	2.04	1.02	1.36	1.20
4.27	0.25	4.57	0.41	4.51	0.36	4.28	0.43	3.89	0.55	4.28	0.75
4.75	0.49	5.14	1.09	5.41	0.93	5.58	0.51	4.70	0.62	5.11	1.01
0.26	0.03	0.24	0.14	0.19	0.17	0.05	0.06	0.15	0.09	0.10	0.08
0.63	0.23	0.58	0.35	0.84	0.23	0.75	0.11	0.77	0.24	0.58	0.29
99.07		99.67		99.56		99.50		99.50		99.57	
22.7	5.7	21.0	9.7	31.0	10.4	25.3	11.0	25.7	12.5	14.8	6.2
860.5	212.7	928.9	436.3	1298.0	410.7	1240.5	617.4	679.1	257.1	688.5	462.5
9.6	1.7	10.5	2.1	5.8	2.1	2.9	1.7	6.8	2.4	2.4	0.9
74.6	19.6	55.9	37.5	50.6	40.9	23.1	13.1	44.6	30.2	21.5	17.1
5.5	3.5	7.0	9.9	14.5	16.6	6.5	3.8	6.5	7.0	4.8	13.7
2.6	1.9	3.7	4.7	4.3	5.3	1.9	1.7	2.1	3.0	2.6	7.9
9.1	3.8	13.6	9.5	18.9	16.9	10.1	8.8	9.1	18.7	6.3	6.1
74.1	8.5	86.3	23.4	60.3	19.1	39.9	14.0	46.9	21.4	54.8	42.8
18.3	1.2	20.5	2.9	11.3	4.7	8.6	2.1	12.8	4.1	15.2	5.2
126.4	24.2	121.9	47.9	233.2	81.8	315.3	81.3	140.5	38.7	127.8	51.8
327.6	39.0	329.4	166.6	308.9	191.0	126.8	108.3	277.7	154.8	160.7	151.6
36.5	1.9	39.2	13.6	30.3	8.7	27.8	7.6	28.2	10.2	42.5	17.2
236.6	83.2	486.3	255.9	408.0	190.7	345.0	140.0	240.0	83.8	368.8	210.3
14.2	1.1	19.1	8.5	21.2	8.1	29.0	8.6	13.6	4.4	19.1	7.2
4.3	0.5	4.1	1.0	4.7	1.5	4.3	2.7	3.2	1.2	3.7	1.2
1.0	0.0	2.7	2.7	6.1	4.2	7.2	4.2	3.9	3.3	2.7	2.7
1.3	1.2	1.6	1.7	10.7	5.3	9.0	4.3	4.1	1.8	0.7	0.6
1424.0	116.2	1099.0	558.0	742.8	360.6	381.9	352.6	961.5	542.3	660.8	482.6
53.3	4.9	64.8	31.7	50.7	13.1	56.3	22.9	50.6	14.8	63.1	30.2
102.7	6.1	131.0	63.2	108.3	30.3	114.0	43.7	100.1	28.5	126.8	59.2
9.2	0.8	13.3	3.1	8.2	1.7	6.9	1.7	9.3	3.0	10.4	3.9
2.5	0.0	3.8	2.1	4.1	1.0	4.5	0.9	2.5	0.0	4.2	2.0
8.0	1.2	11.9	3.5	12.2	3.0	9.9	3.1	12.5	21.1	10.1	3.0
15.9	3.9	15.9	6.6	17.8	6.1	23.4	8.0	16.8	8.1	17.6	11.2
9.2	3.0	9.1	10.7	21.6	13.6	37.5	13.8	14.8	7.3	13.0	9.6
4.8	0.9	3.1	1.7	6.8	3.2	10.4	4.4	4.0	2.4	4.5	2.6
12.25	1.76	8.02	6.40	10.94	6.32	22.13	7.27	22.14	8.29	22.16	9.88
0.00	0.00	0.05	0.18	0.02	0.10	0.12	0.24	0.26	0.36	0.06	0.14
28.50	2.93	31.47	4.81	32.33	5.51	33.36	3.06	28.14	3.71	30.45	6.00
36.71	2.01	38.96	3.48	38.63	3.09	36.65	3.68	33.29	4.70	36.54	6.34
10.08	1.50	9.37	4.48	7.58	4.35	3.30	1.78	8.95	4.23	4.97	4.19
2.88	1.35	2.85	1.48	2.60	2.33	0.79	0.82	0.49	0.74	1.11	1.66
4.65	1.72	4.53	2.26	3.90	2.08	1.41	1.11	3.77	2.10	1.81	1.34
0.00	0.00	0.41	1.09	0.25	1.80	0.00	0.00	0.00	0.00	0.18	1.60
2.64	0.55	2.41	0.96	2.03	0.96	1.36	0.59	1.76	0.90	1.60	0.82
1.69	0.12	1.48	0.56	1.17	0.47	0.58	0.34	0.85	0.38	0.74	0.43

KEY TO ANALYSES (NIS–Numok Intrusive Suite; MBIS–Mount Benedict Intrusive Suite)

7 Long Island Quartz Monzonite
8 (NIS) monzonite to quartz monzonite
9 (MBIS) monzonite to syenite
10 (MBIS) syenite to granite
11 Otter Lake–Walker Lake granite
12 Big River Granite
n^1 Number of analyses for all elements except those listed below
n^2 Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf



KEY TO ROCK TYPES

GBBR–Gabbro
DORT–Diorite
QZDR–Quartz diorite
QZMD–Quartz monzodiorite
MNZN–Monzonite
SENT–Syenite
AFST–Alkali feldspar syenite
QZMZ–Quartz monzonite
QZST–Quartz syenite
AQST–Alkali feldspar quartz syenite
TNLT–Tonalite
GRDR–Granodiorite
MZGT–Monzogranite
GRNT–Granite (ss)
AFGT–Alkali feldspar granite

Figure 38. *Relative abundance of IUGS rock types amongst unclassified plutonic rocks, calculated from normative mineralogy (after Streckeisen and LeMaitre, 1979). Note that this is based on Barth mesonorms, not the CIPW norms listed in tables. Regional sample populations.*

Geochemical Trends and Contrasts

Major-Element Patterns

Major-element patterns (Figure 39) follow expected trends and offer poor unit discrimination. High TiO_2 (also P_2O_5; not figured) contents below 65 percent SiO_2 characterize the Freshsteak and Noarse Lake units. This feature is also shown by the petrographically similar Long Island Quartz Monzonite.

All units show K+N/A (agpaitic index) values below 1.0. A/C+N+K indices are greater than 1.0 in part of the Stag Bay unit, and also in a few samples from the Thunder Mountain and Jeanette Bay units. All other units are wholly metaluminous. Parts of the Stag Bay unit have high (> 0.5) N/N+K ratios and low F/F+M (< 0.8) ratios above 60 percent SiO_2, compared to other units.

Major-element patterns for the granitoid gneiss unit are similar to the overall pattern shown by discrete unclassified units. It includes no peralkaline compositions, but contains some weakly peraluminous rocks.

Trace-Element Patterns

Compatible trace elements (e.g., V) do not discriminate between units (Figures 40 and 41). Rb and Th are highest in the Jeanette Bay and Stag Bay units, consistent with their generally higher SiO_2 contents. Sr, Ba and F are scattered, but high Sr contents partly distinguish the Stag Bay unit. Zr, Y, Nb and Ce provide no distinction between units, although there is some Y enrichment in the Freshsteak unit. Zn is locally enriched in the Freshsteak and Noarse Lake units above 70 percent SiO_2, and Li is enriched in some biotite-rich rocks from the Noarse Lake unit.

The granitoid gneiss unit shows a similar range of trace-element variation. Scattered distributions for LFS trace elements such as Th, Rb, Ba and Sr may, in part, reflect element mobility during subsequent Grenvillian metamorphism, rather than primary magmatic trends.

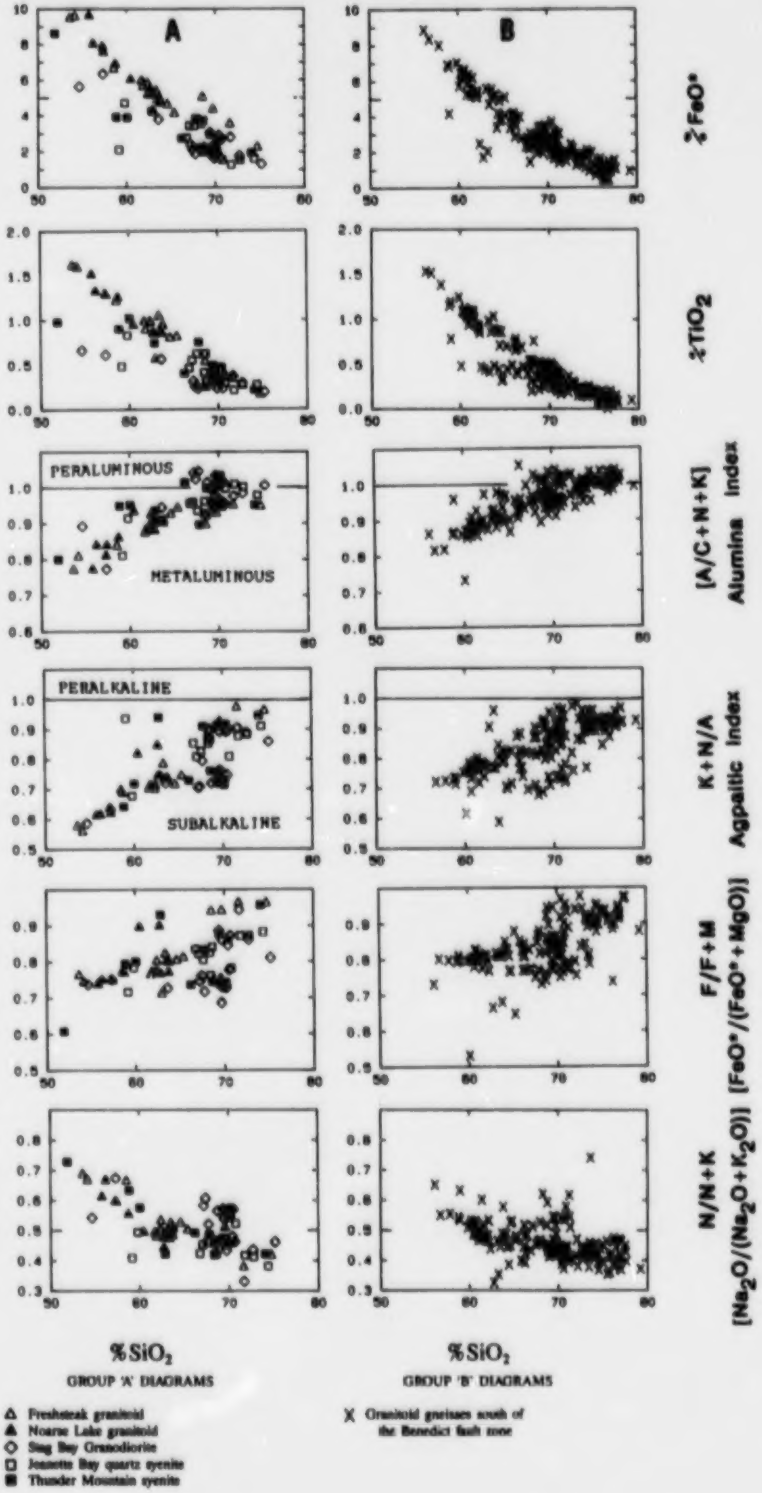


Figure 39. *Variation of selected major elements and derived ratios in unclassified plutonic units.*

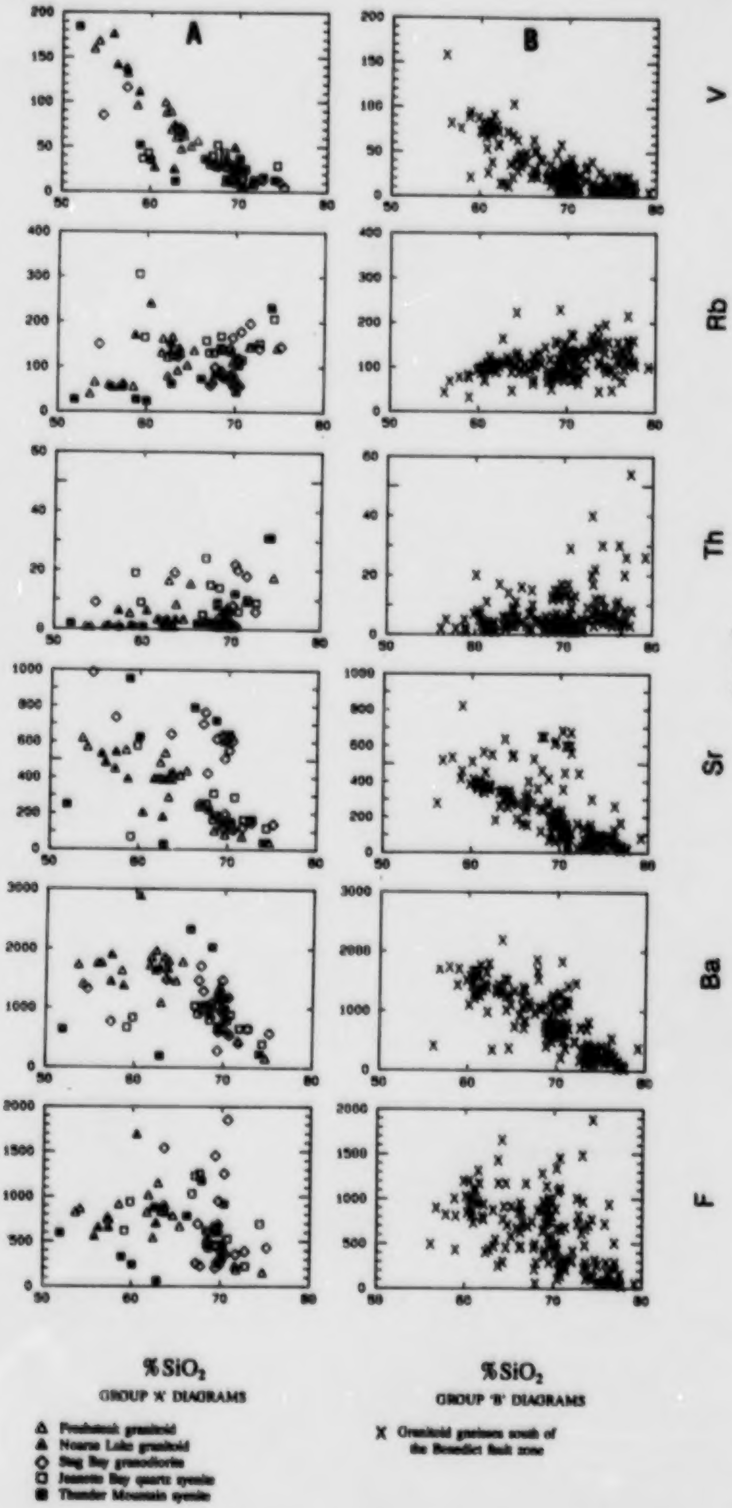


Figure 40. *V, Rb, Th, Sr, Ba and F vs SiO_2 for unclassified plutonic units.*

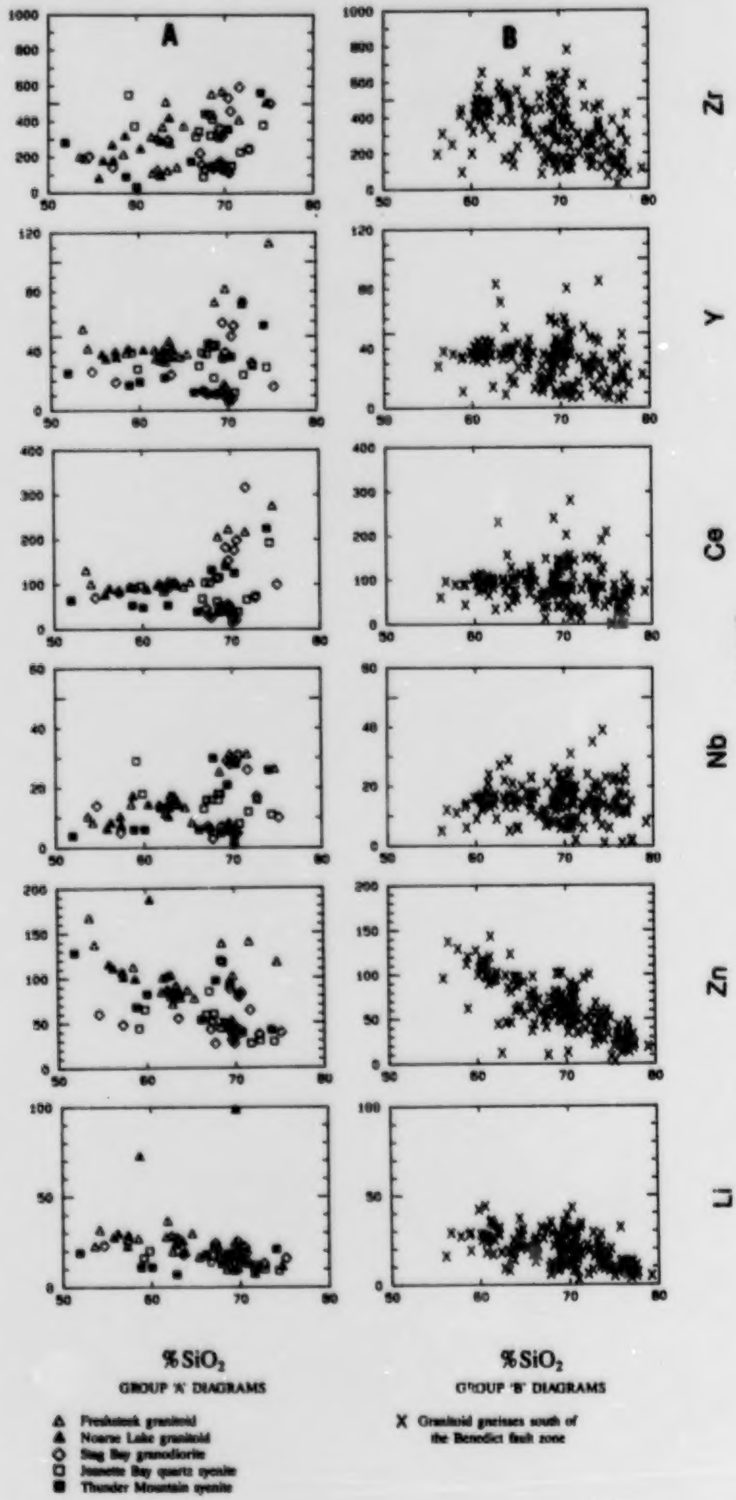


Figure 41. *Zr, Nb, Y, Ce, Li and Zn vs SiO_2 for unclassified plutonic units.*

COMPARATIVE GEOCHEMISTRY

This section covers a number of geochemical aspects in which the emphasis is comparative. Geochemical comparisons are made between the three main plutonic associations described in preceding sections, and the feasibility of using geochemistry to discriminate between them is assessed. Plutonic associations are also discussed in comparison to volcanic suites of broadly similar ages that occur within and adjacent to the study area.

In order to assess the probable tectonic affinities of Central Mineral Belt plutonic suites, Kerr (1989a) conducted a quantitative comparative analysis, using a range of other granitoid batholiths representing varied tectonic settings. No attempt is made here at detailed discussion of this work, but the main points are summarized by the use of selected discriminant diagrams and comparative histograms.

Plutonic suites are also assessed in comparison to 'specialized' granitoid suites that host, or are associated with, metallic mineralization. The emphasis here is to ascertain which units have the greatest potential for granite-related mineralization, and should therefore receive priority of attention in mineral exploration.

COMPARISONS BETWEEN PLUTONIC SUITES

Geochemical Characteristics of Syntectonic Makkovikian Plutonic Rocks

Syntectonic Makkovikian plutonic rocks are divisible into two associations on geochemical grounds. The Long Island Quartz Monzonite and Kennedy Mountain Intrusive Suite define a metaluminous-peralkaline association that shows Fe-enrichment, and evolves to sporadic peralkaline compositions at high silica contents. They define smooth, continous, major- and trace-element trends, that terminate with evolved high-silica granites of the Kennedy Mountain Intrusive Suite. They are regarded here as genetically related (in the sense of having similar origins), and possibly forming a magma sequence derived by fractionation of a single parent magma. In trace-element terms, this association is characterized by distinct enrichment in Fluorine, Zn, HFS elements and REE.

In contrast, the remaining syntectonic Makkovikian granitoid units define a mostly peraluminous association. Peralkaline rocks are absent, and F/F+M ratios are lower at a given SiO_2 content, except for the Melody Granite. These show (as a group) significantly lower F, Zn, HFS element and REE abundances, indicating a quite different origin (or source material). The Pitre Lake granite has a distinct mineralogy and geochemistry (high Li, Rb, Th, low LREE) consistent with field evidence for a metasedimentary source. The Melody Granite is enigmatic; it is variably peraluminous, but in most other respects (including trace-element geochemistry), it is akin to metaluminous-peralkaline granites of the Kennedy Mountain Intrusive Suite, and probably has a similar origin.

Geochemical Characteristics of Posttectonic Makkovikian Plutonic Rocks

A generalized distinction can be made here between the Numok Intrusive Suite and siliceous granitoid rocks. The former is dominated by quartz-poor rock types (monzonite to quartz syenite) that are associated (in the south) with plagiophyric monzodiorite and monzonite of probable cumulate origin.

Siliceous granitoid units, in contrast, are dominated by quartz-rich, K-feldspar porphyritic, commonly fluorite-bearing, biotite or biotite–hornblende granite and alkali-feldspar granite. Although textural and mineralogical differences allow suites and units to be defined amongst these siliceous granitoid rocks, the geochemical similarities between them far outweigh any differences.

Major- and trace-element geochemistry emphasize the continuity of the posttectonic Makkovikian assemblage. The Numok Intrusive Suite is distinct in terms of major-element patterns (i.e., it is less siliceous, but alkali-rich), and also for some compatible and LFS trace elements. However, it has REE, LFS and HFS element contents that are similar to siliceous granitoid units. The latter have very coherent major- and trace-element patterns. There are some absolute differences, e.g., higher F in the Strawberry Intrusive Suite, and higher Zr, Y and REE in the Lanceground Intrusive Suite, and more evolved compositions in both compared to the Big River Granite. However, such distinctions pale in comparison to the overwhelming compositional similarity between all these units.

This geochemical continuity is also geographically continuous; the various units of the Strawberry Intrusive Suite show closely similar characteristics over large lateral distances (about 125 km). Such continuity implies a close similarity in petrogenetic processes and source materials or magmas across this distance, and indicates that a single model is required for all these granites.

Geochemical Similarity of Syntectonic and Posttectonic Makkovikian Plutonic Associations

Table 9 lists average major-element, trace-element and partial CIPW normative compositions for several syn- and posttectonic Makkovikian suites, and emphasizes their similarity. There is a good correspondance between the granites of the Strawberry and Kennedy Mountain Intrusive suites, especially when altered granites with $N/N+K < 0.3$ or > 0.65 are excluded from the latter. This complements their obvious similarity in texture and mineralogy, if the effects of Makkovikian deformation are disregarded. However, alkali disturbance is not present to the same extent in the

Table 9. Comparison of average compositions for selected syntectonic and posttectonic Makkovikian plutonic rocks

ANALYSES	1		2		3		4 (all)		5 (unaltd)		6		7		8		9	
n^1	15		57		40		108		97		197		55		82		79	
n^2	5		12		6		22		23		142		47		66		13	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	63.32	1.27	62.31	4.27	65.52	3.92	73.74	3.09	73.58	2.98	71.29	4.71	72.81	3.56	72.12	2.93	70.11	5.15
TiO_2	0.88	0.06	0.78	0.29	0.63	0.29	0.28	0.18	0.29	0.19	0.31	0.27	0.21	0.11	0.32	0.19	0.39	0.22
Al_2O_3	15.81	0.24	16.69	1.49	15.07	1.21	12.65	1.13	12.67	1.15	13.68	1.55	13.20	1.50	13.22	1.34	14.43	1.74
Fe_2O_3	1.79	0.37	1.72	0.75	1.44	0.61	1.29	0.67	1.24	0.70	1.05	0.74	1.14	0.80	1.21	0.57	1.16	0.55
FeO	3.06	0.73	3.41	1.12	3.66	1.75	1.34	1.13	1.39	1.17	1.68	1.47	1.23	0.81	1.44	0.87	1.49	0.97
MnO	0.10	0.01	0.12	0.05	0.15	0.07	0.06	0.03	0.06	0.02	0.06	0.06	0.05	0.05	0.06	0.04	0.06	0.04
MgO	1.25	0.42	1.22	0.87	0.40	0.29	0.19	0.24	0.19	0.25	0.36	0.50	0.27	0.55	0.18	0.17	0.50	0.84
CaO	2.95	0.48	2.92	1.30	1.76	0.71	0.84	0.61	0.82	0.56	1.14	1.04	0.91	1.17	0.88	0.47	1.36	1.20
Na_2O	4.27	0.25	4.57	0.41	4.51	0.57	4.40	1.08	4.00	0.48	4.09	0.86	4.21	1.26	3.97	0.61	4.28	0.75
K_2O	4.75	0.49	5.14	1.09	5.81	0.67	4.29	1.56	4.85	0.64	5.12	1.10	4.97	1.33	5.47	0.90	5.11	1.01
P_2O_5	0.26	0.03	0.24	0.14	0.15	0.13	0.05	0.05	0.05	0.05	0.07	0.09	0.04	0.03	0.04	0.04	0.10	0.08
LOI	0.63	0.23	0.58	0.35	0.46	0.23	0.45	0.21	0.45	0.22	0.67	0.37	0.67	0.60	0.53	0.20	0.58	0.29
TOTAL	99.07		99.67	0.00	99.54		99.58		99.57		99.52		99.71		99.44		99.57	
(ppm)	Trace elements																	
Li	22.7	5.7	21.0	9.7	13.0	7.6	14.6	11.3	14.9	11.7	25.0	23.5	26.5	23.8	13.9	11.7	14.8	6.2
F	860.5	212.7	928.9	436.3	427.8	270.3	1014.0	847.4	1029.9	803.8	1420.0	1141	1541.1	1021	1244.6	935.7	688.5	462.5
Sc	9.6	1.7	10.5	2.1	11.0	3.8	1.3	0.9	1.4	0.9	3.1	4.1	1.9	1.7	3.8	5.3	2.4	0.9
V	74.6	19.6	55.9	37.5	17.7	10.0	15.6	12.7	15.9	13.4	23.3	29.2	20.4	41.9	12.8	7.7	21.5	17.1
Cr	5.5	3.5	7.0	9.9	3.4	2.4	5.0	3.8	4.7	3.8	5.1	6.5	6.3	7.9	3.7	2.9	4.8	13.7
Ni	2.6	1.9	3.7	4.7	1.1	0.5	1.4	1.2	1.3	1.2	2.2	3.9	2.6	5.8	1.5	1.8	2.6	7.9
Cu	9.1	3.8	13.6	9.5	6.4	3.1	3.8	3.8	3.9	3.9	9.3	38.4	11.3	44.8	6.0	9.2	6.3	6.1
Zn	74.1	8.5	86.3	23.4	114.3	44.2	81.8	53.3	77.1	29.9	75.1	69.6	84.3	82.3	89.6	59.6	54.8	42.8
Ga	18.3	1.2	20.5	2.9	21.6	6.3	16.6	7.3	16.5	6.8	16.9	8.6	17.6	10.2	21.4	10.0	15.2	5.2
Rb	126.4	24.2	121.9	47.9	110.8	54.5	134.6	64.9	153.5	47.1	178.4	65.0	176.1	62.1	172.5	44.1	127.8	51.8
Sr	327.6	39.0	329.4	166.6	108.5	77.0	62.0	75.6	60.8	77.5	111.7	130.2	77.5	71.8	61.2	65.8	160.7	151.6
Y	36.5	1.9	39.2	13.6	53.5	19.9	72.2	30.5	70.9	28.9	55.4	43.8	64.3	46.9	74.4	32.8	42.5	17.2
Zr	236.6	83.2	486.3	255.9	794.8	411.2	388.7	146.8	387.0	151.8	491.5	558.5	471.5	418.2	675.7	439.3	368.8	210.3
Nb	14.2	1.1	19.1	8.5	21.3	6.9	28.3	13.8	27.9	14.0	26.0	21.0	29.9	33.4	29.3	11.1	19.1	7.2
Mo	4.3	0.5	4.1	1.0	3.4	1.1	3.6	1.8	3.7	1.9	4.3	7.7	3.7	2.0	4.3	2.3	3.7	1.2
Sn	1.0	0.0	2.7	2.7	1.3	0.5	3.3	2.1	3.5	2.5	5.8	9.9	5.0	3.2	4.0	2.6	2.7	2.7
Cs	1.3	1.2	1.6	1.7	0.7	0.4	0.7	0.4	0.6	0.4	1.2	1.0	1.1	0.7	1.1	0.7	0.7	0.6
Ba	1424.0	116.2	1099.0	558.0	787.7	542.1	433.8	433.5	453.1	411.7	501.9	382.6	344.9	264.0	329.6	260.1	660.8	482.6
La	53.3	4.9	64.8	31.7	77.2	26.4	78.9	35.2	76.6	33.3	90.7	111.7	75.4	46.8	122.8	62.6	63.1	30.2
Ce	102.7	6.1	131.0	63.2	156.4	54.7	163.1	66.9	158.7	65.7	178.7	197.0	136.9	84.8	247.2	121.1	126.8	59.2
Sm	9.2	0.8	13.3	3.1	14.5	3.8	12.4	3.7	12.6	3.5	13.1	10.4	12.8	6.4	20.8	9.8	10.4	3.9
Yb	2.5	0.0	3.8	2.1	5.3	0.0	7.2	3.6	7.7	3.2	6.6	4.7	7.6	5.1	8.8	4.3	4.2	2.0
Hf	8.0	1.2	11.9	3.5	14.3	5.0	12.2	3.4	12.1	3.1	13.3	13.3	13.3	7.5	19.1	10.3	10.1	3.0
Pb	15.9	3.9	15.9	6.6	15.8	7.1	19.3	10.6	20.3	10.4	37.3	205.3	23.3	9.6	24.5	13.5	17.6	11.2
Th	9.2	3.0	9.1	10.7	5.1	4.8	15.7	9.7	15.2	9.6	18.3	20.5	23.4	28.3	18.9	8.0	13.0	9.6
U	4.8	0.9	3.1	1.7	2.4	1.4	4.8	2.9	4.7	3.0	5.8	7.0	8.0	11.9	5.5	2.3	4.5	2.6
(wt%)	CIPW norms (partial)																	
Q	12.25	1.76	8.02	6.40	10.77	7.74	29.87	6.15	29.80	6.01	24.90	9.23	27.17	8.65	26.22	7.51	22.16	9.88
C	0.00	0.00	0.05	0.18	0.02	0.05	0.01	0.06	0.02	0.06	0.12	0.23	0.07	0.14	0.10	0.70	0.06	0.14
Or	28.50	2.93	31.47	4.81	32.52	5.39	25.57	9.35	28.89	3.89	30.38	5.96	29.63	7.92	32.64	5.34	30.45	6.00
Ab	36.71	2.01	38.96	3.48	40.28	5.86	37.39	8.96	34.11	4.02	34.90	7.35	35.58	10.85	33.79	5.15	36.54	6.34
An	10.08	1.50	9.37	4.48	5.28	3.78	2.16	2.24	2.30	2.27	3.66	2.94	2.43	1.67	1.90	1.64	4.97	4.19
Di	2.88	1.35	2.85	1.48	3.52	2.25	1.15	1.07	1.08	0.87	1.28	2.82	1.25	4.29	1.62	1.35	1.11	1.66
Hy	4.65	1.72	4.53	2.26	3.22	2.08	1.08	1.93	1.22	2.00	2.15	2.26	1.39	1.32	0.96	1.05	1.81	1.34
Ol	0.00	0.00	0.41	1.09	0.61	1.36	0.00	0.00	0.00	0.00	0.03	0.26	0.00	0.02	0.00	0.00	0.18	1.60
Mt	2.64	0.55	2.41	0.96	2.06	0.78	1.63	0.78	1.58	0.75	1.38	1.00	1.25	0.88	1.63	0.77	1.60	0.82
Il	1.69	0.12	1.48	0.56	1.21	0.49	0.54	0.34	0.54	0.36	0.61	0.52	0.39	0.22	0.62	0.36	0.74	0.43

KEY TO ANALYSES (NIS–Numok Intrusive Suite, KMIS–Kennedy Mountain Intrusive Suite, SIS–Strawberry Intrusive Suite, LIS–Lanceground Intrusive Suite)

1	Long Island Quartz Monzonite (all data)
2	Numok Intrusive Suite (Monzonite to Quartz Monzonite)
3	Numok Intrusive Suite (Syenite to Quartz Syenite)
4 (all data)	(KMIS) All data including albitized rocks
5 (unaltd)	(KMIS) Excluding rocks with N/N+K < 0.3 or > 0.65
n^1	Number of analyses for all elements except those listed below
n^2	Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf
6	Strawberry Intrusive Suite (all data)
7	Cape Strawberry granite and related rocks
8	Lanceground Intrusive Suite (all data)
9	Big River Granite (all data)

Strawberry Intrusive Suite, although there are signs of some minor effects. The Long Island Quartz Monzonite and Numok Intrusive Suite have rather similar major-element compositions, but dissimilar trace-element patterns. It should also be noted that there are strong similarities between the Long Island Quartz Monzonite and the mainly undeformed Freshsteak granitoid, now known to be of Makkovikian age on the basis of Rb–Sr isotopic data. The peraluminous granites of the syntectonic Makkovikian association, however, have no clear equivalent amongst the posttectonic suites.

Further illustration of the similarities between syn- and posttectonic Makkovikian assemblages can be obtained by comparison of equivalent variation diagrams (Figures 16, 17, 18 and 19, and Figures 22, 23, 24 and 25).

Geochemical Characteristics of Labradorian Plutonic Rocks

Labradorian plutonic rocks include at least two contrasting associations, which appear to have been derived from mafic and silicic parental magmas respectively. Consequently, the most striking geochemical feature of the Labradorian assemblage is its compositional bimodality. The Adlavik Intrusive Suite and the Mount Benedict Intrusive Suite, although compositionally distinct, represent closely related, probably complementary associations. Both are products of the fractionation of mafic magmas; the Adlavik Intrusive Suite represents (for the most part) mafic mineral and plagioclase cumulates, and preserves evidence of multiple intrusive events. The Mount Benedict Intrusive Suite represents the evolved residual magmas produced by this fractionation, which underwent further evolution by feldspar fractionation. The petrographic and geochemical features of both suites are supportive of this interpretation, and the feasibility of a genetic link is illustrated by trace-element modelling (Kerr, 1989a).

Labradorian granitic (*ss*) rocks are of diverse affinity. They include a number of small, probably high-level granite plutons, such as the Monkey Hill Intrusive Suite, and also coarse-grained units of regional extent that have rather unremarkable geochemical features.

Contrasts between Labradorian and Makkovikian Plutonic Associations

Labradorian plutonic rocks differ from their Makkovikian counterparts in several respects. First, the Makkovikian assemblage does not include layered mafic intrusions such as the Adlavik Intrusive Suite, although such rocks might be present below the present level of exposure (there are, for example, mafic inclusions in the border zone of the Numok Intrusive Suite). Second, Labradorian granitoid rocks do not evolve to the weakly peralkaline compositions typical of syn- and posttectonic Makkovikian granites. They are instead mostly of slightly peraluminous character, especially above 70 percent SiO_2.

These contrasts are summarized in Table 10, which lists mean compositions for units of similar SiO_2 content in both Makkovikian and Labradorian assemblages. At a given SiO_2 value, Labradorian intrusions are poorer in fluorine, HFS (e.g., Zr, Nb, Hf) elements and REE (e.g., La, Ce, Sm, Yb). They show no sign of Zn enrichment at higher SiO_2 contents. LFS element abundances are similar in both assemblages, except for the Mount Benedict Intrusive Suite, which is enriched relative to all other units of equivalent or higher SiO_2. This suite also has F and Zr contents (particularly at 62 to 67 percent SiO_2) that approach those of some Makkovikian units, but are depleted at higher SiO_2 contents.

It must be stressed that, in spite of these differences, Makkovikian and Labradorian plutonic rocks exhibit extensive geochemical overlap. It is therefore difficult to classify single samples or small sample suites on the basis of geochemistry alone. However, on a regional unit scale, geochemistry can be used to discriminate between Labradorian and Makkovikian granitoid rocks.

Geochemical Comparisons of Plutonic and Volcanic Assemblages

As outlined earlier, there are at least two discrete volcanic assemblages in the area, which appear to correspond in age (at least in part) with Makkovikian and Labradorian plutonic suites. No geochemical data on the volcanic suites are presented here; however, Kerr (1989a) compiled existing geochemical data, and supplemented them with new analyses of the Upper Aillik Group, in order to evaluate the compositional affinities between intrusive and extrusive suites.

Table 11 compares the average compositions of volcanic and hypabyssal intrusive rocks assigned to the Upper Aillik Group to granitoid plutonic units that have similar major-element compositions. With the exception of fluorine, trace-element patterns for the Upper Aillik Group are very close to those of the Kennedy Mountain, Strawberry and Lanceground Intrusive suites. They also resemble patterns from the posttectonic Makkovikian Big River Granite (not listed). High Zn, Zr, Y and Nb contents are characteristic of all, but the plutonic rocks have higher REE abundances. Hypabyssal intrusive rocks show the closest similarity (including high fluorine); this is particularly so for the White Bear Mountain porphyry and the spatially associated Tarun granite. Differences in fluorine content between volcanic and plutonic associations are to be expected, as volatile components would be lost in extrusive environments. The HFS element and REE patterns for the Upper Aillik Group are dissimilar to those of most Labradorian plutonic rocks of equivalent major-element composition, although Zr contents are similar to parts of the Mount Benedict Intrusive Suite. LFS element patterns of all units are broadly similar; however, the Upper Aillik Group shows great scatter, and generally higher Sr contents than most plutonic rocks.

The close compositional similarity between the Upper Aillik Group and Makkovikian high-silica granites is

consistent with, but not definitive of, a genetic link between them. It is also consistent with geochronological data from at least some of the extrusive rocks, which have yielded ages of ca. 1810 Ma (Schärer *et al.*, 1988).

Previous studies of the Upper Aillik Group, and the new data collected by Kerr (1989a) yield clear evidence of soda and potash metasomatism in the volcanic rocks. Such patterns have been recognized in mineralized areas of the Upper Aillik Group for some time (e.g., White and Martin, 1980), but the data of Kerr (1989a) suggest that such patterns are a regional feature of the group. There is a striking similarity between these alteration patterns and those identified in the foliated granites of the Kennedy Mountain Intrusive Suite. If these alteration patterns are indeed manifestations of the same event, it indicates that alteration was post-volcanic, rather than syn-volcanic with respect to extrusion of the Upper Aillik Group. The strong compositional similarity between the Upper Aillik Group and the Kennedy Mountain Intrusive Suite (Table 11) may also indicate that they are in part equivalent, and both have undergone equivalent late Makkovikian deformation. However, such equivalence is difficult to prove, without precise dates and evaluation of the proportions of ca. 1850 and 1800 Ma volcanism, in the Upper Aillik Group.

Geochemical contrasts between granites of the Makkovikian and Labradorian plutonic assemblages are relatively subtle, as discussed above, and their compositions overlap. Kerr (1989a) compared Labradorian plutonic suites to the data of Ryan (1984) from the ca. 1650 Ma Bruce River Group volcanic rocks, and found that geochemical contrasts between the Upper Aillik Group and Bruce River Group were generally analogous to those between their plutonic equivalents, as shown in Table 10.

GEOCHEMICAL AFFINITIES AND TECTONIC SETTINGS OF MAKKOVIKIAN AND LABRADORIAN PLUTONIC ROCKS

The geochemical affinity and tectonic setting of plutonic suites in the eastern Central Mineral Belt is important both in the context of the regional geology and tectonic development of Labrador, and also from the perspective of mineral potential, because specific metallogenic assemblages are associated with particular granitoid types and environments. Kerr (1989a) attempted to assess these aspects via a quantitative comparative study, using several large datasets from a variety of settings in direct comparisons. This section summarizes some of the main points, and illustrates them with selected diagrams.

Comparative Assemblages

Volcanic-arc batholiths are represented by data from Mesozoic to Cenozoic, circum-Pacific batholiths of Peru (Pitcher *et al.*, 1985), Chile (M. Brown, unpublished data) and southern California (Baird and Miesch, 1984). All are associated with active or recently active zones where oceanic crust is subducted beneath a continental margin. Collisional environments representing later stages of orogenesis are represented by Cenozoic granitoid rocks from the Himalayan belt of Afghanistan (Debon *et al.*, 1987), and by the late- to post-orogenic Paleozoic granites of the Newfoundland Appalachians (Strong *et al.*, 1974, and unpublished data from the Geological Survey database). Within-plate, or 'anorogenic' granitoid batholiths are represented by Middle Proterozoic granitoid rocks from Flowers River in northern Labrador (Hill, 1982; and unpublished data from J. McConnell, 1993), which are closely similar in petrology to Phanerozoic anorogenic suites such as those of West Africa (e.g., Kinnaird and Bowden, 1987). All of these databases include large amounts of generally representative data, allowing the use of extensive parameters such as frequency spectra, abundance of rock types and evolutionary trends as comparative tools, in addition to conventional intensive methods such as discrimination diagrams. Some selected aspects of comparisons are summarized below.

Major-Element Frequency Spectra

SiO_2

Magmatic arc assemblages (e.g., Peru, Chile) have broad, approximately normal, frequency distributions with maxima at 57 to 65 percent SiO_2 (Figure 42); those from California are displaced to slightly higher SiO_2. All arc assemblages have expanded SiO_2 frequency distributions. In contrast, Newfoundland and Afghanistan (Cenozoic), and Flowers River, have asymmetric, negatively-skewed distributions with maxima at 71 to 77 percent SiO_2.

The Makkovikian and Labradorian plutonic assemblages both have bimodal SiO_2 histograms; in Labradorian rocks, the lesser peak is at gabbro–diorite composition, compared to monzonite–syenite in the Makkovikian rocks. In general, Makkovikian rocks resemble collisional or within-plate assemblages, and are completely distinct from volcanic-arc assemblages.

MgO

MgO frequency spectra (Figure 43) are superficially similar for all assemblages. However, collisional and within-plate assemblages are strongly depleted in MgO relative to volcanic arcs. Makkovikian suites resemble both collisional and within-plate assemblages, but more closely resemble the latter. Labradorian suites show a wide range of MgO (mostly reflecting the mafic rocks of the Adlavik and Mount Benedict Intrusive suites), but are also dominated by MgO-poor compositions compared to arc assemblages.

N/N+K [$Na_2O/(Na_2O + K_2O)$]

Arc assemblages are predominantly sodic ($Na_2O > K_2O$), and have broad, normal to negatively skewed, frequency

Table 10. Comparison of average compositions for selected syntectonic and posttectonic Makkovikian plutonic units, with Labradorian plutonic units of similar composition

ANALYSES	1		2		3		4		5		6	
n[1]	15		57		40		137		97		197	
n[2]	5		12		6		62		23		142	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	63.32	1.27	62.31	4.27	65.52	3.92	66.40	6.28	73.58	2.98	71.29	4.71
TiO_2	0.88	0.06	0.78	0.29	0.63	0.29	0.50	0.31	0.29	0.19	0.31	0.27
Al_2O_3	15.81	0.24	16.69	1.49	15.07	1.21	15.50	1.69	12.67	1.15	13.68	1.55
Fe_2O_3	1.79	0.37	1.72	0.75	1.44	0.61	1.27	0.62	1.24	0.70	1.05	0.74
FeO	3.06	0.73	3.41	1.12	3.66	1.75	2.07	1.45	1.39	1.17	1.68	1.47
MnO	0.10	0.01	0.12	0.05	0.15	0.07	0.07	0.04	0.06	0.02	0.06	0.06
MgO	1.25	0.42	1.22	0.87	0.40	0.29	0.96	1.19	0.19	0.25	0.36	0.50
CaO	2.95	0.48	2.92	1.30	1.76	0.71	2.08	1.84	0.82	0.56	1.14	1.04
Na_2O	4.27	0.25	4.57	0.41	4.51	0.57	4.38	0.42	4.00	0.48	4.09	0.86
K_2O	4.75	0.49	5.14	1.09	5.81	0.67	5.27	0.98	4.85	0.64	5.12	1.10
P_2O_5	0.26	0.03	0.24	0.14	0.15	0.13	0.15	0.18	0.05	0.05	0.07	0.09
LOI	0.63	0.23	0.58	0.35	0.46	0.23	0.85	0.30	0.45	0.22	0.67	0.37
TOTAL	99.07		99.67	0.00	99.54		99.49		99.57		99.52	
(ppm)	Trace elements											
Li	22.7	5.7	21.0	9.7	13.0	7.6	28.5	11.3	14.9	11.7	25.0	23.5
F	860.5	212.7	928.9	436.3	427.8	270.3	1229.8	524.6	1029.9	803.8	1420.0	1141
Sc	9.6	1.7	10.5	2.1	11.0	3.8	4.0	2.3	1.4	0.9	3.1	4.1
V	74.6	19.6	55.9	37.5	17.7	10.0	44.3	40.6	15.9	13.4	23.3	29.2
Cr	5.5	3.5	7.0	9.9	3.4	2.4	14.0	32.0	4.7	3.8	5.1	6.5
Ni	2.6	1.9	3.7	4.7	1.1	0.5	5.1	16.3	1.3	1.2	2.2	3.9
Cu	9.1	3.8	13.6	9.5	6.4	3.1	19.3	23.5	3.9	3.9	9.3	38.4
Zn	74.1	8.5	86.3	23.4	114.3	44.2	54.3	24.6	77.1	29.9	75.1	69.6
Ga	18.3	1.2	20.5	2.9	21.6	6.3	11.0	5.0	16.5	6.8	16.9	8.6
Rb	126.4	24.2	121.9	47.9	110.8	54.5	260.5	99.6	153.5	47.1	178.4	65.0
Sr	327.6	39.0	329.4	166.6	108.5	77.0	276.6	258.1	60.8	77.5	111.7	130.2
Y	36.5	1.9	39.2	13.6	53.5	19.9	28.3	8.1	70.9	28.9	55.4	43.8
Zr	236.6	83.2	486.3	255.9	794.8	411.2	356.3	174.2	387.0	151.8	491.5	558.5
Nb	14.2	1.1	19.1	8.5	21.3	6.9	23.7	10.1	27.9	14.0	26.0	21.0
Mo	4.3	0.5	4.1	1.0	3.4	1.1	4.5	2.4	3.7	1.9	4.3	7.7
Sn	1.0	0.0	2.7	2.7	1.3	0.5	6.9	4.3	3.5	2.5	5.8	9.9
Cs	1.3	1.2	1.6	1.7	0.7	0.4	9.6	4.7	0.6	0.4	1.2	1.0
Ba	1424.0	116.2	1099.0	558.0	787.7	542.1	612.5	440.7	453.1	411.7	501.9	382.6
La	53.3	4.9	64.8	31.7	77.2	26.4	52.6	18.7	76.6	33.3	90.7	111.7
Ce	102.7	6.1	131.0	63.2	156.4	54.7	108.8	37.3	158.7	65.7	178.7	197.0
Sm	9.2	0.8	13.3	3.1	14.5	3.8	7.4	1.8	12.6	3.5	13.1	10.4
Yb	2.5	0.0	3.8	2.1	5.3	0.0	4.4	0.9	7.7	3.2	6.6	4.7
Hf	8.0	1.2	11.9	3.5	14.3	5.0	10.8	3.4	12.1	3.1	13.3	13.3
Pb	15.9	3.9	15.9	6.6	15.8	7.1	19.9	7.9	20.3	10.4	37.3	205.3
Th	9.2	3.0	9.1	10.7	5.1	4.8	27.7	16.7	15.2	9.6	18.3	20.5
U	4.8	0.9	3.1	1.7	2.4	1.4	8.1	4.4	4.7	3.0	5.8	7.0
(wt%)	CIPW norms (partial)											
Q	12.25	1.76	8.02	6.40	10.77	7.74	15.19	9.84	29.80	6.01	24.90	9.23
C	0.00	0.00	0.05	0.18	0.02	0.05	0.07	0.19	0.02	0.06	0.12	0.23
Or	28.50	2.93	31.47	4.81	32.52	5.39	31.52	5.81	28.89	3.89	30.38	5.96
Ab	36.71	2.01	38.96	3.48	40.28	5.86	37.51	3.57	34.11	4.02	34.90	7.35
An	10.08	1.50	9.37	4.48	5.28	3.78	7.01	6.36	2.30	2.27	3.66	2.94
Di	2.88	1.35	2.85	1.48	3.52	2.25	1.98	2.21	1.08	0.87	1.28	2.82
Hy	4.65	1.72	4.53	2.26	3.22	2.08	3.07	2.89	1.22	2.00	2.15	2.26
Ol	0.00	0.00	0.41	1.09	0.61	1.36	0.37	1.71	0.00	0.00	0.03	0.26
Mt	2.64	0.55	2.41	0.96	2.06	0.78	1.81	0.93	1.58	0.75	1.38	1.00
Il	1.69	0.12	1.48	0.56	1.21	0.49	0.97	0.60	0.54	0.36	0.61	0.52

KEY TO ANALYSES (STM–syntect Makkovikian; PTM–posttect Makkovikian; L–Labradorian)

1 Long Island Quartz Monzonite (all data) [STM]
2 Numok Intrusive Suite (Monzonite to quartz monzonite) [PTM]
3 Numok Intrusive Suite (Syenite to quartz syenite) [PTM]
4 Mount Benedict Intrusive Suite (all data) [L]
5 Kennedy Mountain Intrusive Suite (all data, unaltered) [STM]
6 Strawberry Intrusive Suite (all data) [PTM]
n[1] Number of analyses for all elements except those listed below
n[2] Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 10. *(Continued)*

7		8		9		10		11		12	
82		4		70		34		79		49	
66				57		29		13		11	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
72.12	2.93	72.73	1.26	73.50	4.42	73.24	3.22	70.11	5.15	68.54	4.42
0.32	0.19	0.16	0.09	0.14	0.12	0.15	0.11	0.39	0.22	0.44	0.20
13.22	1.34	14.66	0.44	13.49	1.18	13.98	1.49	14.43	1.74	14.98	1.62
1.21	0.57	0.64	0.44	1.08	3.23	0.61	0.45	1.16	0.55	1.20	0.61
1.44	0.87	0.66	0.29	0.70	1.56	0.62	0.31	1.49	0.97	1.87	1.01
0.06	0.04	0.03	0.01	0.05	0.04	0.04	0.01	0.06	0.04	0.06	0.03
0.18	0.17	0.65	0.27	0.21	0.24	0.18	0.13	0.50	0.84	0.86	0.54
0.88	0.47	0.99	0.03	0.76	0.44	0.78	0.36	1.36	1.20	2.04	1.02
3.97	0.61	5.06	0.93	4.26	1.07	4.27	1.11	4.28	0.75	3.89	0.55
5.47	0.90	3.34	1.46	4.72	1.22	4.98	0.87	5.11	1.01	4.70	0.62
0.04	0.04	0.06	0.02	0.03	0.03	0.02	0.03	0.10	0.08	0.15	0.09
0.53	0.20	0.93	0.29	0.58	0.27	0.50	0.13	0.58	0.29	0.77	0.24
99.44		99.91		99.48		99.37		99.57		99.50	
13.9	11.7	11.5	1.7	20.5	13.6	20.7	19.8	14.8	6.2	25.7	12.5
1244.6	935.7	187.5	68.4	511.7	436.6	177.7	120.6	688.5	462.5	679.1	257.1
3.8	5.3			1.4	1.2	1.9	1.2	2.4	0.9	6.8	2.4
12.8	7.7	21.5	8.5	17.4	18.1	14.6	6.8	21.5	17.1	44.6	30.2
3.7	2.9	7.5	5.7	4.0	6.4	3.5	3.8	4.8	13.7	6.5	7.0
1.5	1.8	3.0	2.7	1.4	1.3	1.7	2.1	2.6	7.9	2.1	3.0
6.0	9.2	3.5	1.3	9.2	20.2	3.8	3.7	6.3	6.1	9.1	18.7
89.6	59.6	29.3	3.9	34.9	30.5	28.8	10.9	54.8	42.8	46.9	21.4
21.4	10.0	6.8	1.7	12.0	6.6	11.7	5.8	15.2	5.2	12.8	4.1
172.5	44.1	96.5	41.0	181.7	71.7	191.1	68.2	127.8	51.8	140.5	38.7
61.2	65.8	273.5	47.5	134.5	210.4	87.1	75.8	160.7	151.6	277.7	154.8
74.4	32.8	5.8	1.7	26.5	23.0	25.3	20.2	42.5	17.2	28.2	10.2
675.7	439.3	88.0	38.0	160.1	99.3	185.6	172.3	368.8	210.3	240.0	83.8
29.3	11.1	2.0	0.0	17.2	8.5	20.8	13.6	19.1	7.2	13.6	4.4
4.3	2.3	2.0	0.0	84.5	578.7	28.1	142.9	3.7	1.2	3.2	1.2
4.0	2.6			2.9	2.3	2.4	2.1	2.7	2.7	3.9	3.3
1.1	0.7			2.2	2.1	1.9	1.3	0.7	0.6	4.1	1.8
329.6	260.1	912.5	446.6	391.2	360.5	519.0	675.5	660.8	482.6	961.5	542.3
122.8	62.6	13.8	4.6	22.1	21.4	30.9	22.3	63.1	30.2	50.6	14.8
247.2	121.1	19.0	11.6	45.4	43.8	63.2	45.7	126.8	59.2	100.1	28.5
20.8	9.8			4.4	4.0	4.2	1.9	10.4	3.9	9.3	3.0
8.8	4.3			3.9	3.6	2.8	0.6	4.2	2.0	2.5	0.0
19.1	10.3			5.6	3.0	5.6	1.5	10.1	3.0	12.5	21.1
24.5	13.5	12.5	7.9	22.6	9.2	26.8	11.5	17.6	11.2	16.8	8.1
18.9	8.0	1.8	1.0	13.6	8.5	19.1	9.2	13.0	9.6	14.8	7.3
5.5	2.3	1.7	0.5	6.0	5.1	7.4	5.0	4.5	2.6	4.0	2.4
26.22	7.51	27.56	2.39	28.99	5.57	26.82	9.65	22.16	9.88	22.14	8.29
0.10	0.70	0.98	0.48	0.25	0.24	0.26	0.21	0.06	0.14	0.26	0.36
32.64	5.34	19.88	8.64	27.82	7.14	29.78	5.21	30.45	6.00	28.14	3.71
33.79	5.15	43.23	8.08	36.63	8.56	36.39	9.20	36.54	6.34	33.29	4.70
1.90	1.64	4.84	0.26	3.22	1.70	3.61	1.64	4.97	4.19	8.95	4.23
1.62	1.35	0.00	0.00	0.25	0.72	0.16	0.41	1.11	1.66	0.49	0.74
0.96	1.05	2.12	0.72	0.86	0.99	0.87	0.62	1.81	1.34	3.77	2.10
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	1.60	0.00	0.00
1.63	0.77	0.94	0.64	1.29	4.96	0.82	0.46	1.60	0.82	1.76	0.90
0.62	0.36	0.31	0.17	0.26	0.22	0.30	0.22	0.74	0.43	0.85	0.38

KEY TO ANALYSES (STM–syntectonic Makkovikian; PTM–posttectonic Makkovikian; L–Labradorian)

7 Lanceground Intrusive Suite (all data) [PTM]
8 Brumwater granite [STM]
9 Monkey Hill Intrusive Suite (all data) [L]
10 Witchdoctor and Burnt Lake granites (all data) [L]
11 Big River Granite (all data) [PTM]
12 Otter Lake–Walker Lake granite (all data) [L]
n^1 Number of analyses for all elements except those listed below
n^2 Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 11. Comparison of average compositions of volcanic assemblages to Makkovikian and Labradorian plutonic units of similar major-element composition

ANALYSES	1		2		3		4		5		6		7	
n[1]	13		5		16		14		97		197		82	
n[2]	3		5		15		13		22		142		66	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	72.81	3.54	75.42	1.56	74.26	3.29	71.27	3.99	73.58	2.98	71.29	4.71	72.12	2.93
TiO_2	0.32	0.22	0.22	0.08	0.23	0.11	0.36	0.11	0.29	0.19	0.31	0.27	0.32	0.19
Al_2O_3	13.61	1.59	11.75	0.24	12.49	1.35	13.61	1.80	12.67	1.15	13.68	1.55	13.22	1.34
Fe_2O_3	1.47	1.10	1.86	0.78	1.65	0.56	1.82	0.88	1.24	0.70	1.05	0.74	1.21	0.57
FeO	0.60	0.62	1.20	0.50	0.77	0.67	0.79	0.46	1.39	1.17	1.68	1.47	1.44	0.87
MnO	0.04	0.02	0.05	0.02	0.04	0.02	0.06	0.02	0.06	0.02	0.06	0.06	0.06	0.04
MgO	0.44	0.40	0.07	0.06	0.23	0.52	0.28	0.28	0.19	0.25	0.36	0.50	0.18	0.17
CaO	1.09	0.93	0.52	0.22	0.59	0.59	1.19	1.13	0.82	0.56	1.14	1.04	0.88	0.47
Na_2O	4.02	1.90	5.62	1.60	4.08	1.62	3.90	0.28	4.00	0.48	4.09	0.86	3.97	0.61
K_2O	4.67	2.89	2.22	2.17	4.77	2.81	5.52	0.45	4.85	0.64	5.12	1.10	5.47	0.90
P_2O_5	0.07	0.06	0.02	0.00	0.03	0.03	0.04	0.04	0.05	0.05	0.07	0.09	0.04	0.04
LOI	0.69	0.38	0.46	0.28	0.44	0.22	0.57	0.31	0.45	0.22	0.67	0.37	0.53	0.20
TOTAL	99.83		99.41		99.58		99.41		99.57		99.52		99.44	
(ppm)	Trace elements													
Li	16.5	19.0	7.4	8.8	11.7	15.4	13.1	6.2	14.9	11.7	25.0	23.5	13.9	11.7
F	378.5	339.8	331.8	346.3	272.0	401.2	541.1	343.2	1029.9	803.8	1420.0	1141	1244.6	935.7
Sc	1.7	0.9	1.8	1.4	2.2	1.9	4.8	2.7	1.4	0.9	3.1	4.1	3.8	5.3
V	21.1	9.6	11.4	1.7	18.4	22.1	13.3	9.9	15.9	13.4	23.3	29.2	12.8	7.7
Cr	6.0	10.4	7.2	11.8	7.6	8.2	5.9	3.7	4.7	3.8	5.1	6.5	3.7	2.9
Ni	2.5	3.3	5.4	9.8	1.4	1.5	2.0	2.8	1.3	1.2	2.2	3.9	1.5	1.8
Cu	4.2	3.4	14.6	24.3	4.7	3.7	6.9	8.8	3.9	3.9	9.3	38.4	6.0	9.2
Zn	44.0	34.1	66.8	64.9	86.1	81.0	77.8	41.7	77.1	29.9	75.1	69.6	89.6	59.6
Ga	12.6	4.3	24.2	6.7	15.4	6.9	11.5	6.7	16.5	6.8	16.9	8.6	21.4	10.0
Rb	138.1	105.8	56.4	48.2	139.4	86.2	168.2	28.8	153.5	47.1	178.4	65.0	172.5	44.1
Sr	156.4	144.7	48.8	35.1	53.4	46.3	140.9	226.4	60.8	77.5	111.7	130.2	61.2	65.8
Y	32.0	24.3	71.2	22.4	54.7	32.2	69.9	17.1	70.9	28.9	55.4	43.8	74.4	32.8
Zr	317.3	155.6	593.6	354.3	529.8	264.6	490.4	129.4	387.0	151.8	491.5	558.5	675.7	439.3
Nb	15.5	7.1	33.8	19.5	27.8	10.7	29.2	7.6	27.9	14.0	26.0	21.0	29.3	11.1
Mo	2.9	1.2	14.0	22.5	7.4	15.2	2.8	1.1	3.7	1.9	4.3	7.7	4.3	2.3
Sn	3.0	3.5	9.2	9.4	5.2	2.8	6.4	2.9	3.5	2.5	5.8	9.9	4.0	2.6
Cs	1.0	0.9	0.5	0.0	1.0	0.9	1.3	0.5	0.6	0.4	1.2	1.0	1.1	0.7
Ba	695.3	593.1	540.6	643.1	507.8	517.6	512.4	189.2	453.1	411.7	501.9	382.6	329.6	260.1
La	40.8	32.0	43.0	33.0	62.8	42.0	86.2	22.8	76.6	33.3	90.7	111.7	122.8	62.6
Ce	85.8	63.1	122.2	53.0	138.7	74.2	180.6	40.3	158.7	65.7	178.7	197.0	247.2	121.1
Sm	11.6	10.0	12.1	4.1	12.6	7.0	13.4	3.5	12.6	3.5	13.1	10.4	20.8	9.8
Yb	5.8	2.9	8.3	3.8	7.5	4.0	7.9	1.6	7.7	3.2	6.6	4.7	8.8	4.3
Hf	10.3	5.7	17.0	5.2	14.6	6.9	13.3	2.6	12.1	3.1	13.3	13.3	19.1	10.3
Pb	14.9	8.3	9.6	3.7	20.7	12.5	24.0	9.1	20.3	10.4	37.3	205.3	24.5	13.5
Th	7.2	4.7	13.6	4.2	12.2	7.9	22.6	6.6	15.2	9.6	18.3	20.5	18.9	8.0
U	2.7	1.3	4.3	0.6	5.6	3.4	7.9	3.5	4.7	3.0	5.8	7.0	5.5	2.3
(Wt%)	CIPW norms (partial)													
Q	25.59	10.28	33.48	1.88	31.06	7.58	25.18	6.96	29.80	6.01	24.90	9.23	26.22	7.51
C	0.45	0.74	0.00	0.00	0.05	0.11	0.00	0.01	0.02	0.06	0.12	0.23	0.10	0.70
Or	27.68	17.87	13.23	12.91	28.38	16.68	32.96	2.68	28.89	3.89	30.38	5.96	32.64	5.34
Ab	35.12	16.65	47.18	12.78	34.37	14.19	33.38	2.36	34.11	4.02	34.90	7.35	33.79	5.15
An	4.45	4.15	0.73	0.59	1.79	3.01	3.36	4.90	2.30	2.27	3.66	2.94	1.90	1.64
Di	0.50	0.68	1.07	1.25	0.42	0.48	1.09	0.67	1.08	0.87	1.28	2.82	1.62	1.35
Hy	1.42	1.41	0.51	1.13	0.81	2.07	0.47	0.77	1.22	2.00	2.15	2.26	0.96	1.05
Ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.26	0.00	0.00
Mt	0.49	0.86	1.92	1.13	1.22	0.97	1.24	0.78	1.58	0.75	1.38	1.00	1.63	0.77
Il	0.52	0.37	0.42	0.15	0.42	0.21	0.68	0.22	0.54	0.36	0.61	0.52	0.62	0.36

KEY TO ANALYSES (UAG—Upper Aillik Group)

1 (UAG) Undivided volcanic and volcaniclastic rocks
2 (UAG) Early sequence of Gower and Ryan (1988)
3 (UAG) Late sequence of Gower and Ryan (1988)
4 (UAG) Hypabyssal intrusive rocks
5 Kennedy Mountain Intrusive Suite
6 Strawberry Intrusive Suite
7 Lanceground Intrusive Suite
n[1] Number of analyses for all elements except those listed below
n[2] Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 11. *(Continued)*

8		9		10		11		12		13		14	
41		11		21		70		34		67		49	
31		11		6		57		29		39		11	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
72.84	2.75	72.28	1.25	71.62	4.37	73.50	4.42	73.24	3.22	70.69	3.31	68.54	4.42
0.30	0.11	0.35	0.06	0.26	0.13	0.14	0.12	0.15	0.11	0.30	0.18	0.44	0.20
12.99	1.34	13.32	0.55	14.15	2.08	13.49	1.18	13.98	1.49	14.39	1.06	14.98	1.62
1.07	0.39	1.57	0.33	1.28	0.55	1.08	3.23	0.61	0.45	0.97	0.40	1.20	0.61
1.35	0.68	0.73	0.33	0.70	0.51	0.70	1.56	0.62	0.31	1.09	0.66	1.87	1.01
0.06	0.03	0.06	0.02	0.05	0.02	0.05	0.04	0.04	0.01	0.05	0.02	0.06	0.03
0.17	0.15	0.21	0.09	0.50	0.55	0.21	0.24	0.18	0.13	0.38	0.27	0.86	0.54
0.82	0.42	0.81	0.25	1.40	1.13	0.76	0.44	0.78	0.36	0.97	0.49	2.04	1.02
3.92	0.66	3.90	0.27	3.72	1.10	4.26	1.07	4.27	1.11	4.28	0.43	3.89	0.55
5.42	0.67	5.67	0.30	4.81	1.17	4.72	1.22	4.98	0.87	5.58	0.51	4.70	0.62
0.04	0.02	0.04	0.02	0.06	0.04	0.03	0.03	0.02	0.03	0.05	0.06	0.15	0.09
0.50	0.18	0.46	0.09	0.95	0.72	0.58	0.27	0.50	0.13	0.75	0.11	0.77	0.24
99.48		99.48		99.50		99.48		99.37		99.50		99.50	
14.6	15.2	12.5	4.2	19.0	14.7	20.5	13.6	20.7	19.8	25.3	11.0	25.7	12.5
1084.7	763.1	588.6	340.5	540.7	491.0	511.7	436.6	177.7	120.6	1240.5	617.4	679.1	257.1
3.2	1.7	4.5	1.0	3.4	1.4	1.4	1.2	1.9	1.2	2.9	1.7	6.8	2.4
13.8	7.4	11.5	6.3	25.8	14.8	17.4	18.1	14.6	6.8	23.1	13.1	44.6	30.2
3.8	3.3	5.3	3.0	19.0	55.3	4.0	6.4	3.5	3.8	6.5	3.8	6.5	7.0
1.8	2.4	1.4	1.2	5.3	14.9	1.4	1.3	1.7	2.1	1.9	1.7	2.1	3.0
4.7	3.5	8.2	9.6	6.9	5.1	9.2	20.2	3.8	3.7	10.1	8.8	9.1	18.7
82.8	59.0	69.4	34.6	44.9	22.9	34.9	30.5	28.8	10.9	39.9	14.0	46.9	21.4
16.2	7.3	8.7	1.0	7.8	1.7	12.0	6.6	11.7	5.8	8.6	2.1	12.8	4.1
167.1	52.5	176.3	20.4	156.3	58.2	181.7	71.7	191.1	68.2	315.3	81.3	140.5	38.7
60.0	68.8	86.5	34.8	216.6	187.0	134.5	210.4	87.1	75.8	126.8	108.3	277.7	154.8
75.5	29.3	63.1	11.8	25.2	9.4	26.5	23.0	25.3	20.2	27.8	7.6	28.2	10.2
560.7	280.9	446.5	106.6	262.5	78.8	160.1	99.3	185.6	172.3	345.0	140.0	240.0	83.8
29.2	10.1	26.8	3.7	14.2	5.6	17.2	8.5	20.8	13.6	29.0	8.6	13.6	4.4
3.6	1.5	2.6	0.9	2.6	0.9	84.5	578.7	28.1	142.9	4.3	2.7	3.2	1.2
4.2	2.8	5.7	2.2	2.3	1.4	2.9	2.3	2.4	2.1	7.2	4.2	3.9	3.3
1.1	0.7	1.5	0.5	1.3	1.6	2.2	2.1	1.9	1.3	9.0	4.3	4.1	1.8
308.1	244.0	550.1	155.9	648.6	495.3	391.2	360.5	519.0	675.5	381.9	352.6	961.5	542.3
104.7	36.4	78.8	17.4	40.5	14.8	22.1	21.4	30.9	22.3	56.3	[illegible]	50.6	14.8
211.9	71.6	166.4	30.9	82.8	30.0	45.4	43.8	63.2	45.7	114.0	43.7	100.1	28.5
18.0	6.6	12.5	2.9	7.9	4.0	4.4	4.0	4.2	1.9	6.9	1.7	9.3	3.0
8.5	2.9	7.5	1.1	4.0	1.5	3.9	3.6	2.8	0.6	4.5	0.9	2.5	0.0
16.8	7.0	12.6	2.1	9.0	2.2	5.6	3.0	5.6	1.5	9.9	3.1	12.5	21.1
24.7	12.0	25.5	8.6	18.1	10.2	22.6	9.2	26.8	11.5	23.4	8.0	16.8	8.1
22.3	7.3	21.5	4.4	8.6	6.9	13.6	8.5	19.1	9.2	37.5	13.8	14.8	7.3
6.3	2.4	7.6	1.8	5.8	1.9	6.0	5.1	7.4	5.0	10.4	4.4	4.0	2.4
27.49	7.01	26.50	3.51	28.41	10.34	28.99	5.57	26.82	9.65	22.13	7.27	22.14	8.29
0.01	0.05	0.01	0.02	0.72	2.21	0.25	0.24	0.26	0.21	0.12	0.24	0.26	0.36
32.33	3.97	33.83	1.81	28.83	6.97	27.82	7.14	29.78	5.21	33.36	3.06	28.14	3.71
33.46	5.51	33.32	2.32	31.92	9.40	36.63	8.56	36.39	9.20	36.65	3.68	33.29	4.70
1.84	1.57	2.11	1.03	5.87	5.51	3.22	1.70	3.61	1.64	3.30	1.78	8.95	[illegible]
1.50	1.17	0.89	0.38	0.41	0.89	0.25	0.72	0.16	0.41	0.79	0.82	0.49	[illegible]
0.92	0.89	0.27	0.55	1.35	1.85	0.86	0.99	0.87	0.62	1.41	1.11	3.77	2.10
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.50	0.57	1.24	0.69	1.21	0.64	1.29	4.96	0.82	0.46	1.36	0.59	1.76	0.90
0.57	0.20	0.67	0.11	0.46	0.27	0.26	0.22	0.30	0.22	0.58	0.34	0.85	0.38

KEY TO ANALYSES:

- 8 (Lanceground Intrusive Suite) Tarun granite
- 9 (UAG) White Bear Mountain porphyry body
- 10 (JEA) Volcanic and volcaniclastic rocks
- 11 Monkey Hill Intrusive Suite
- n[1] Number of analyses for all elements except those listed below
- 12 Witchdoctor and Burnt Lake granites
- 13 Mount Benedict Intrusive Suite (granitic unit
- 14 Otter Lake–Walker Lake granite
- n[2] Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

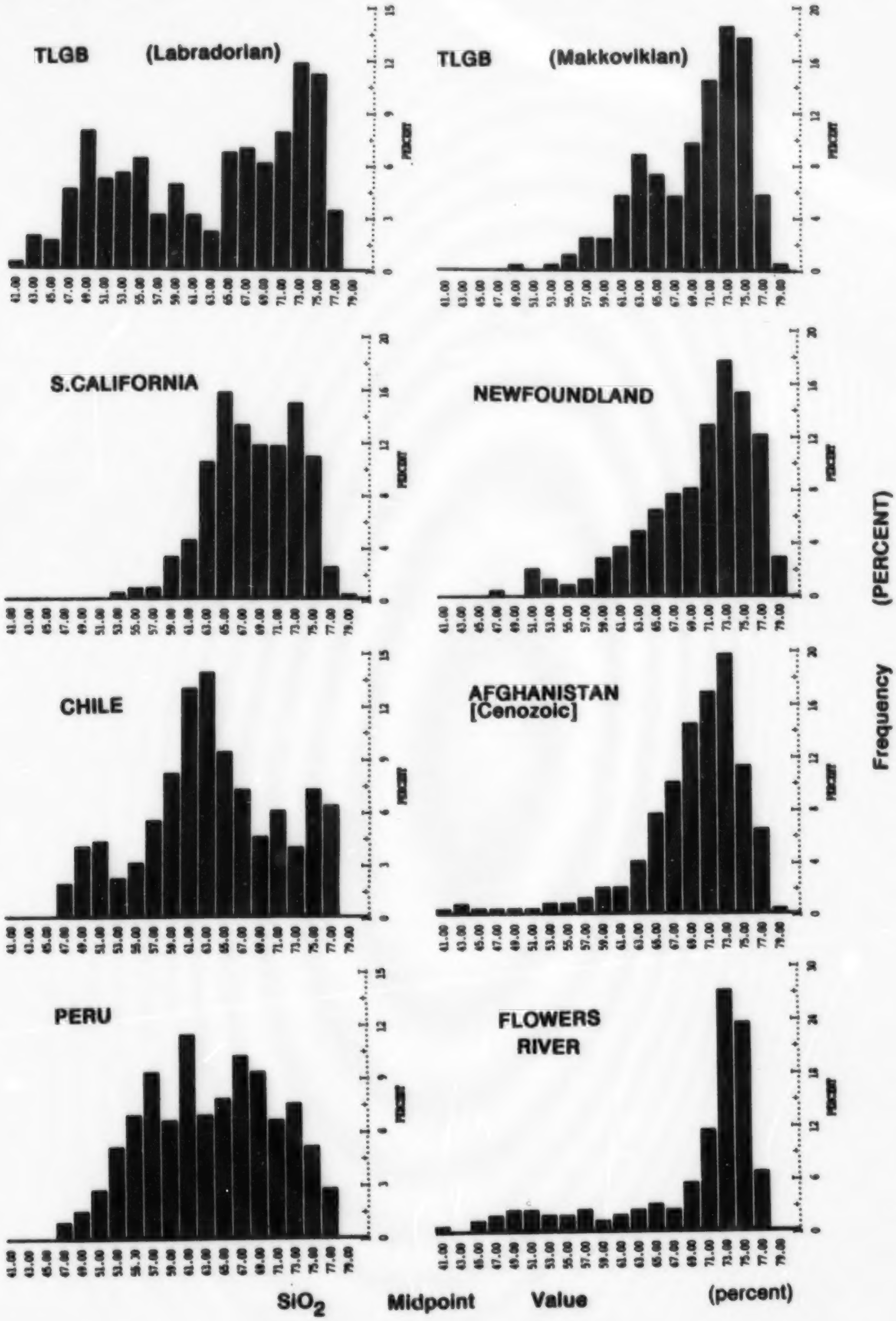


Figure 42. *Comparative SiO_2 frequency spectra.*

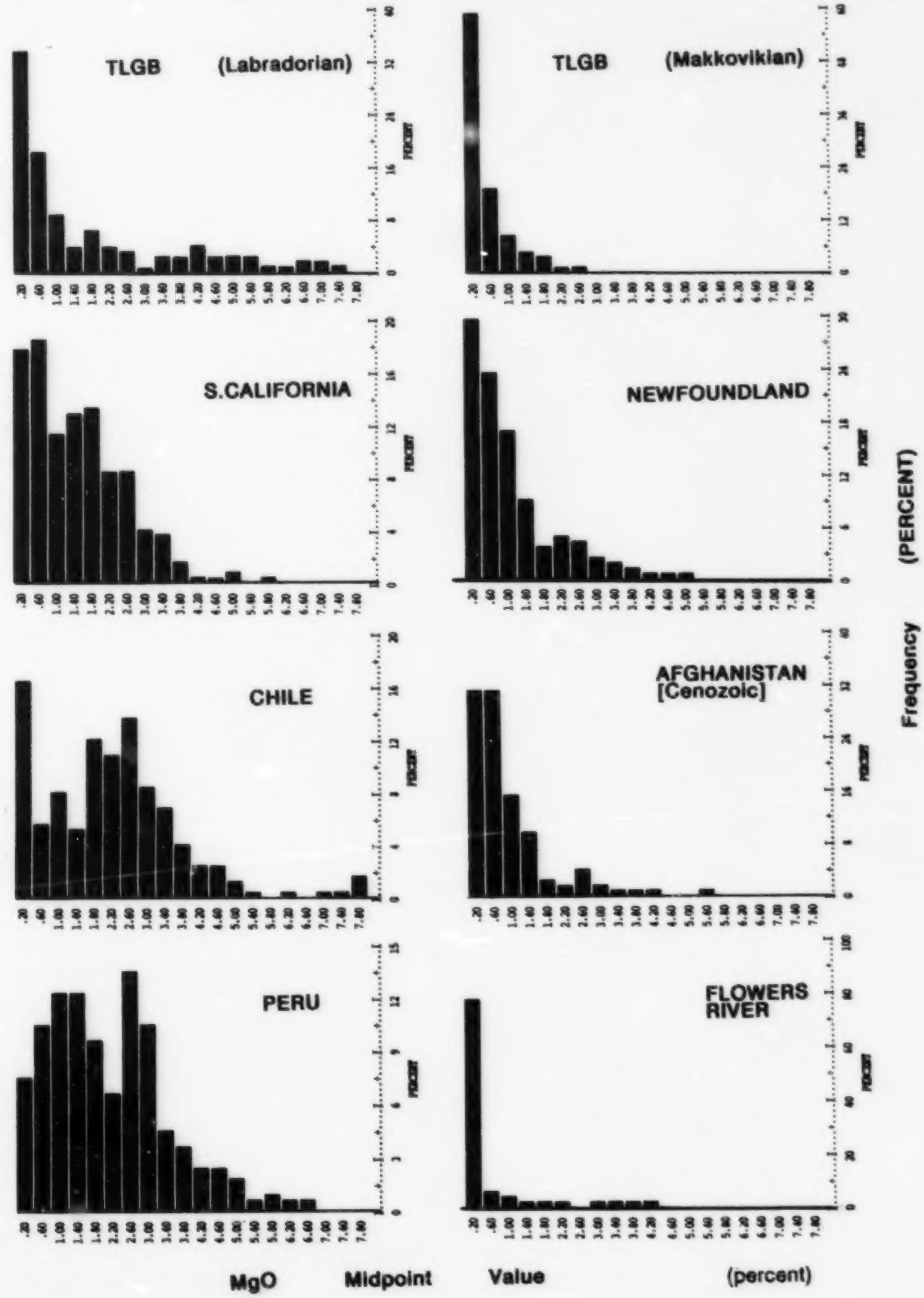


Figure 43. *Comparative MgO frequency spectra.*

spectra (Figure 44). They contrast strongly with the narrow, positively skewed, potassic ($K_2O > Na_2O$) frequency distributions of collisional and within-plate assemblages.

The Makkovikian assemblage is closely similar to Newfoundland and Afghanistan (Cenozoic) assemblages, but also resembles Flowers River. The Labradorian spectrum is unique, but is clearly potassic relative to the arc assemblages.

K+N/A [Agpaitic Index]

Arc assemblages have positively skewed, commonly bimodal patterns with maxima between 0.5 and about 0.7 (Figure 45); they do not include peralkaline rocks. Collisional assemblages have a more restricted range (maxima about 0.8), and Newfoundland includes about 7 percent peralkaline compositions.

The Makkovikian assemblage is similar to the Newfoundland assemblage, but has distinctly higher K+N/A at 0.9 to 1.0. The Labradorian assemblage is bimodal, but includes some rocks with similarly high K+N/A values. Neither TLGB assemblage is as extreme in composition as Flowers River, where about 60 percent of compositions are peralkaline.

Major-Element Geochemical Trends

The contrasts in compositional anatomy described above via frequency spectra are placed in an evolutionary context in the Q'−ANOR diagram (Figure 46) of Streckeisen and LeMaitre (1979), which shows the general distribution of rock types. Arc assemblages have quasi-linear trends extending from gabbro to granite (*ss*), but cluster primarily in the quartz and anorthite-rich tonalite and granodiorite fields. Collisional assemblages are shifted to more evolved compositions (monzogranite to granite), but lie essentially on the same 'quartz-rich' evolutionary trend.

In contrast, both TLGB assemblages have arcuate, 'quartz-poor' trends that proceed from gabbro to alkali-feldspar granite via monzonite and syenite. The Flowers River assemblage, although restricted in compositional range, has a similar quartz-poor evolutionary trend, but is virtually anorthite-free at silicic compositions. These trends are analogous to those defined by Bowden *et al.* (1984) using the ternary Quartz−Plagioclase−Alkali-feldspar modal diagram, where 'within-plate' assemblages such as the Nigerian younger granites have similar quartz-poor evolutionary trends.

These quartz-rich and quartz-poor trends are clearly visible also in the Q−Ab−Or system (Figure 47), where the TLGB and Flowers River assemblages have well-defined trends that commence at the Ab−Or join at about Or 40, and evolve to the ternary minumum area. These correspond to the general location of the plagioclase−alkali-feldspar cotectic at low pressures and An content (James and Hamilton, 1969). In contrast, the evolutionary trends of arc-type suites, and also post-orogenic granites from Newfoundland, lie predominantly within the plagioclase stability field, although they also terminate close to the ternary minumum of the granite system.

Trace-Element 'Fingerprints' for Granitoid Rocks

A considerable effort has been directed toward the development of discrimination methods for igneous suites from different tectonic settings. 'Discriminant diagrams' of this type are constructed by empirical methods, usually with data from well-known, preferably Mesozoic or younger, 'type assemblages'. Although their usefulness for defining the setting of ancient suites is questioned by many geologists (including this author), there is no doubt that they provide convenient methods for summarizing trace-element data.

In the Rb−(Y+Nb) logarithmic plot (Figure 48) of Pearce *et al.* (1984), a good separation of Makkovikian and Labradorian assemblages is visible. Makkovikian plutonic rocks fall mostly in the within-plate-granite (WPG) field, whereas Labradorian intrusive rocks fall mostly within the volcanic-arc-granite (VAG) field. There is some overlap around the triple point area of the diagram. Makkovikian plutonic rocks are distinctly different from Mesozoic arc granitoid suites from Chile, but partly correspond with post-orogenic Newfoundland granites, and anorogenic granites from northern Labrador. The apparent similarity between Labradorian plutonic rocks and those from Chile is slightly misleading, as the Labradorian assemblage includes gabbro and diorite (Adlavik Intrusive Suite) whereas the Chile database is dominated by quartz diorites, tonalites and granodiorites. Similar results are shown by the Y−Nb logarithmic plot of Pearce *et al.* (1984), which is not illustrated.

Brown *et al.* (1984) defined an 'arc spectrum' using a range of diagrams, including the (Rb/Zr)−Nb plot (Figure 49). In this diagram, the Makkovikian assemblage lies outside the arc spectrum; its lower Rb/Zr ratios are a function of Zr enrichment, rather than Rb depletion. The similarity to post-orogenic granitoid suites from Newfoundland is also apparent. The Labradorian assemblage and Chilean arc-related suites both lie within the arc spectrum, but the Labradorian assemblage has more 'mature' characteristics.

Whalen *et al.* (1987) compiled data from a number of granitoid suites that have been termed 'A-type granites', where the 'A' denotes characteristics such as anhydrous, anorogenic or alkaline. In their Zr−(Ga/Al) diagram (Figure 50), Makkovikian plutonic rocks correspond mostly to A-type granites, although they have lower Ga/Al and Zr compared to the true anorogenic granites from Flowers River. Labradorian intrusive rocks lie mostly in the 'other' field−in this case, 'I-type' granites; they correspond well with arc-related granitoid rocks from Chile. The (K_2O +

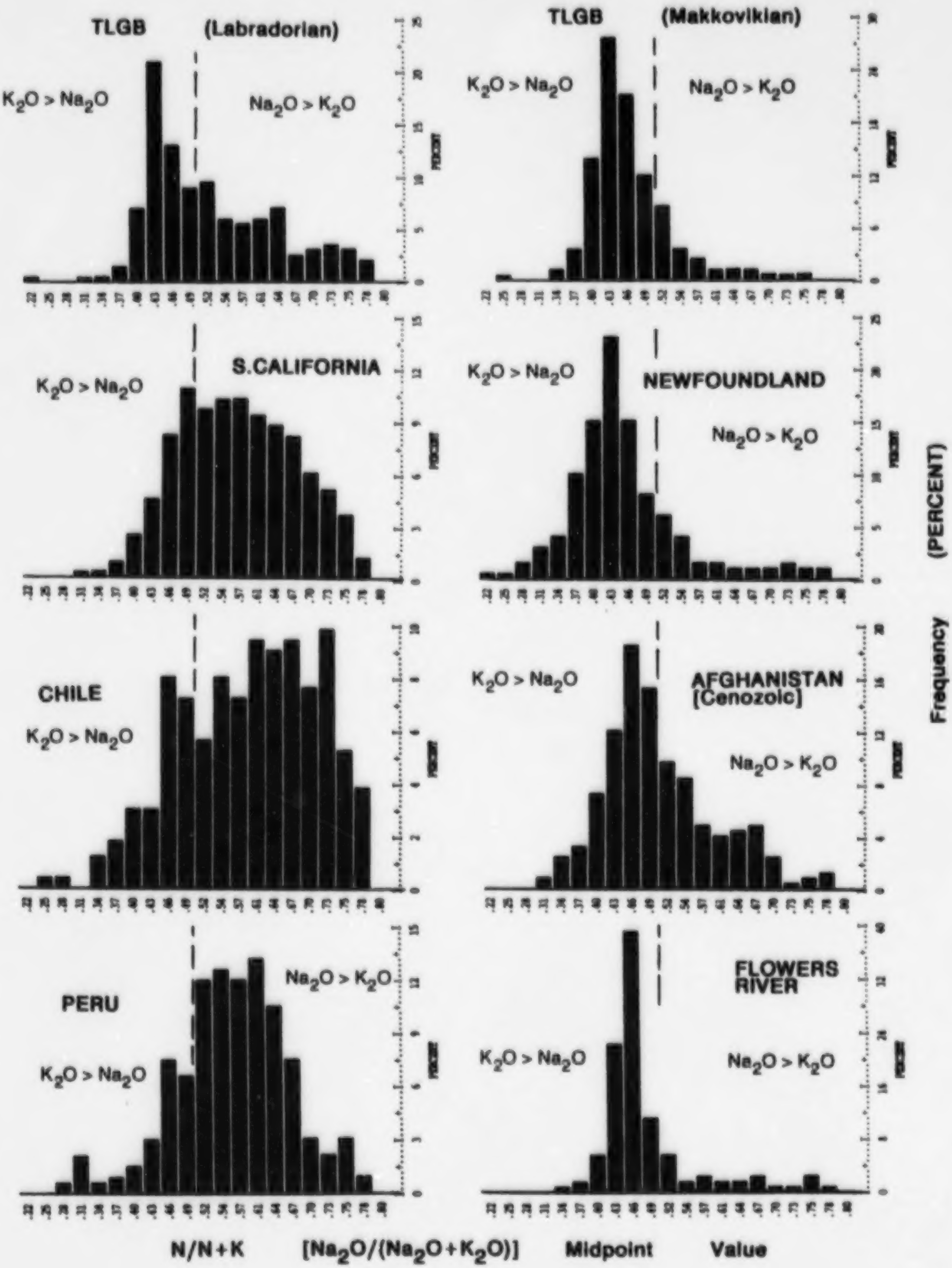


Figure 44. *Comparative N/N+K frequency spectra.*

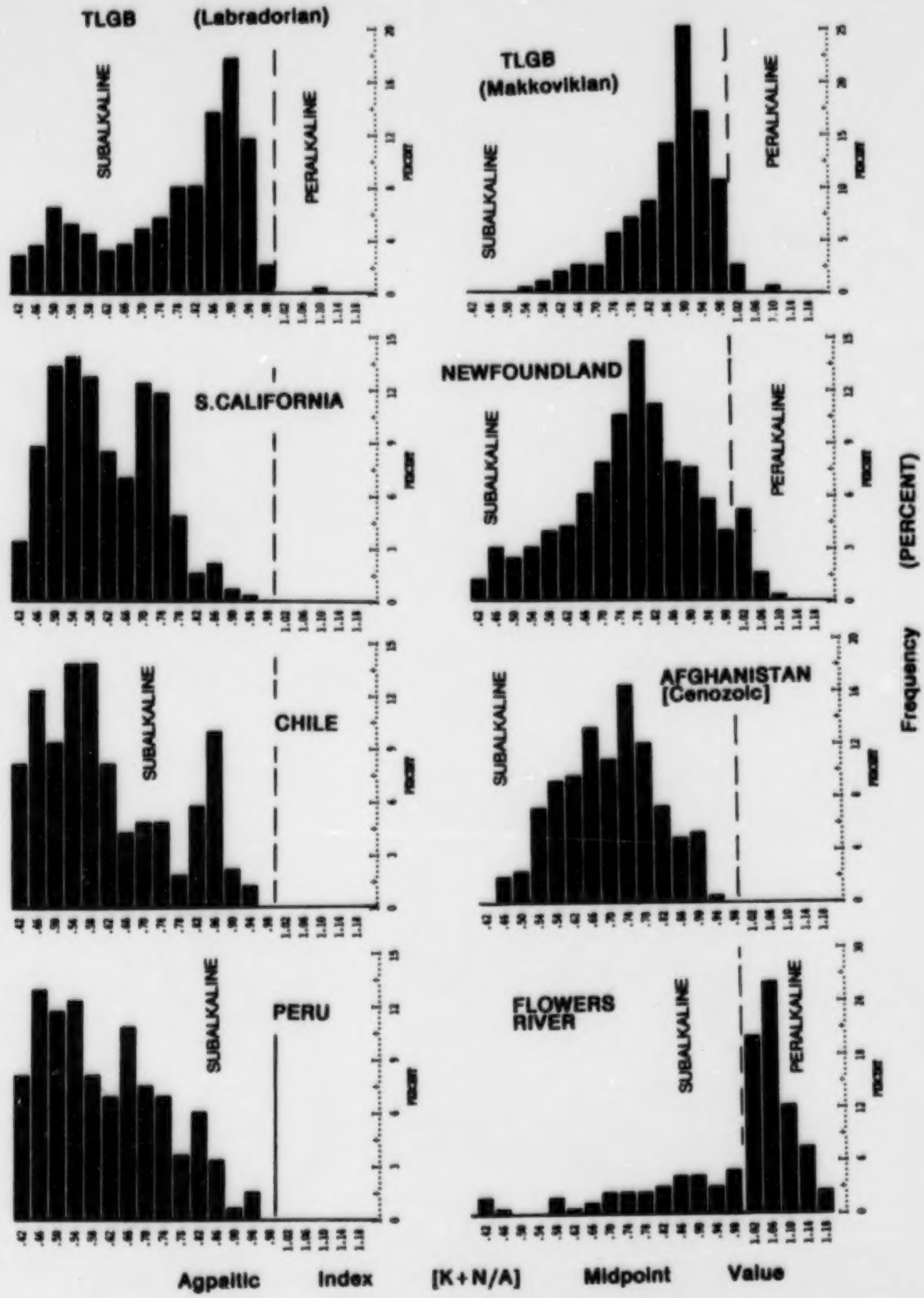


Figure 45. *Comparative Agpaitic Index frequency spectra.*

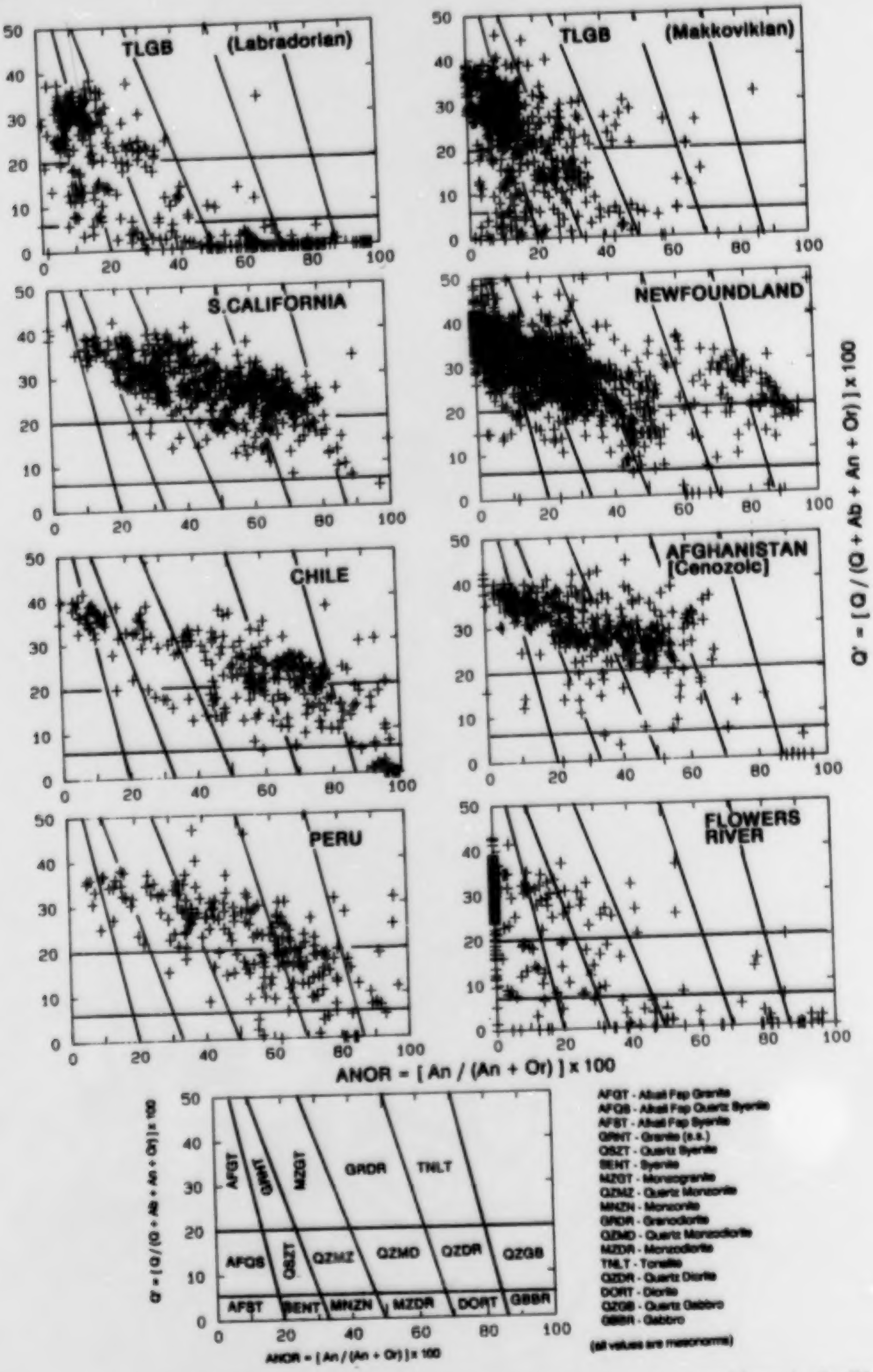


***Figure 46.** Distribution of the Makkovikian, Labradorian and comparative plutonic assemblages in the Q'–ANOR diagram of Streckeisen and LeMaitre (1979).*

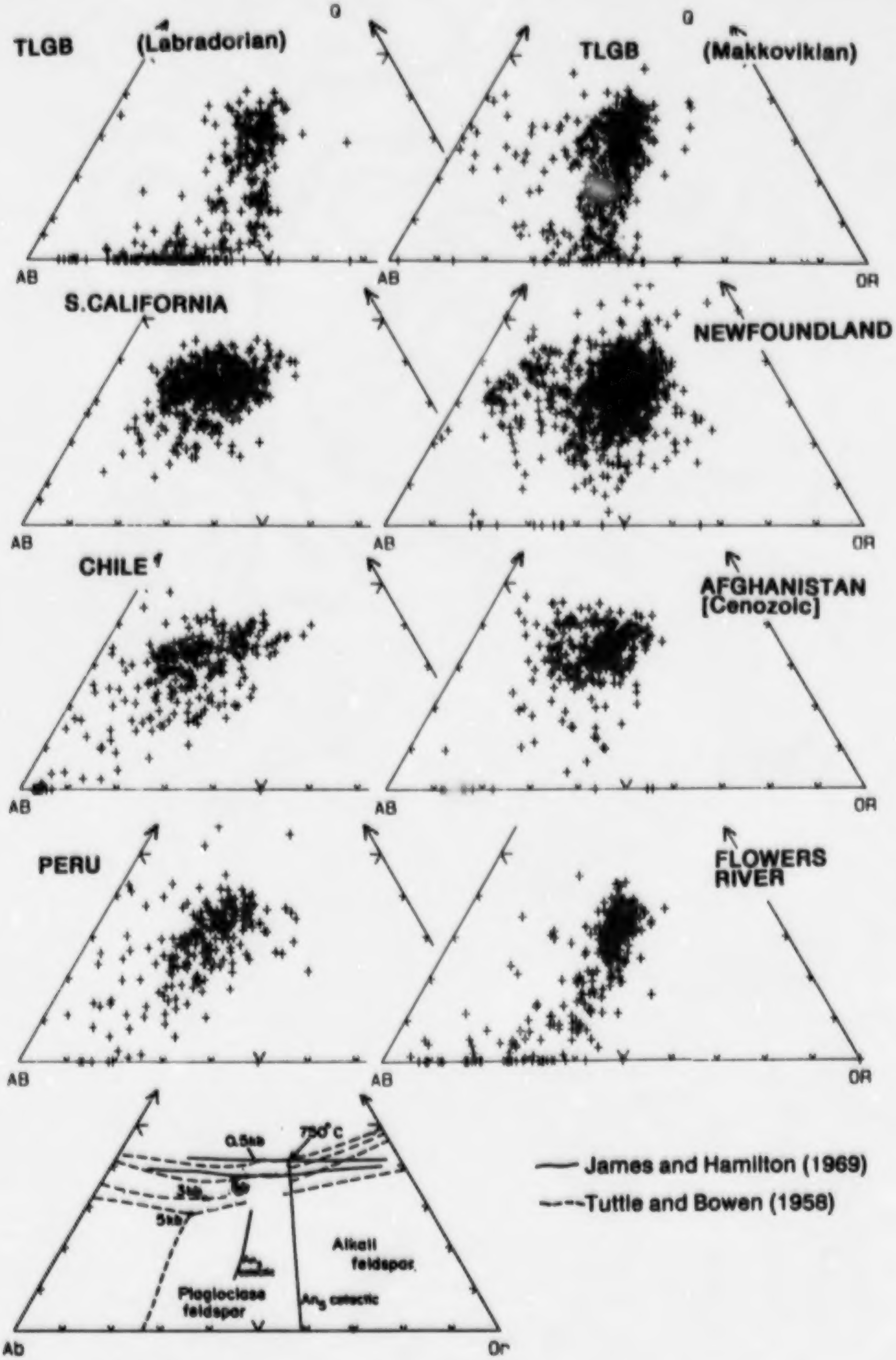


Figure 47. *Distribution of the Makkovikian, Labradorian and comparative plutonic assemblages in the quartz–albite–orthoclase ternary system.*

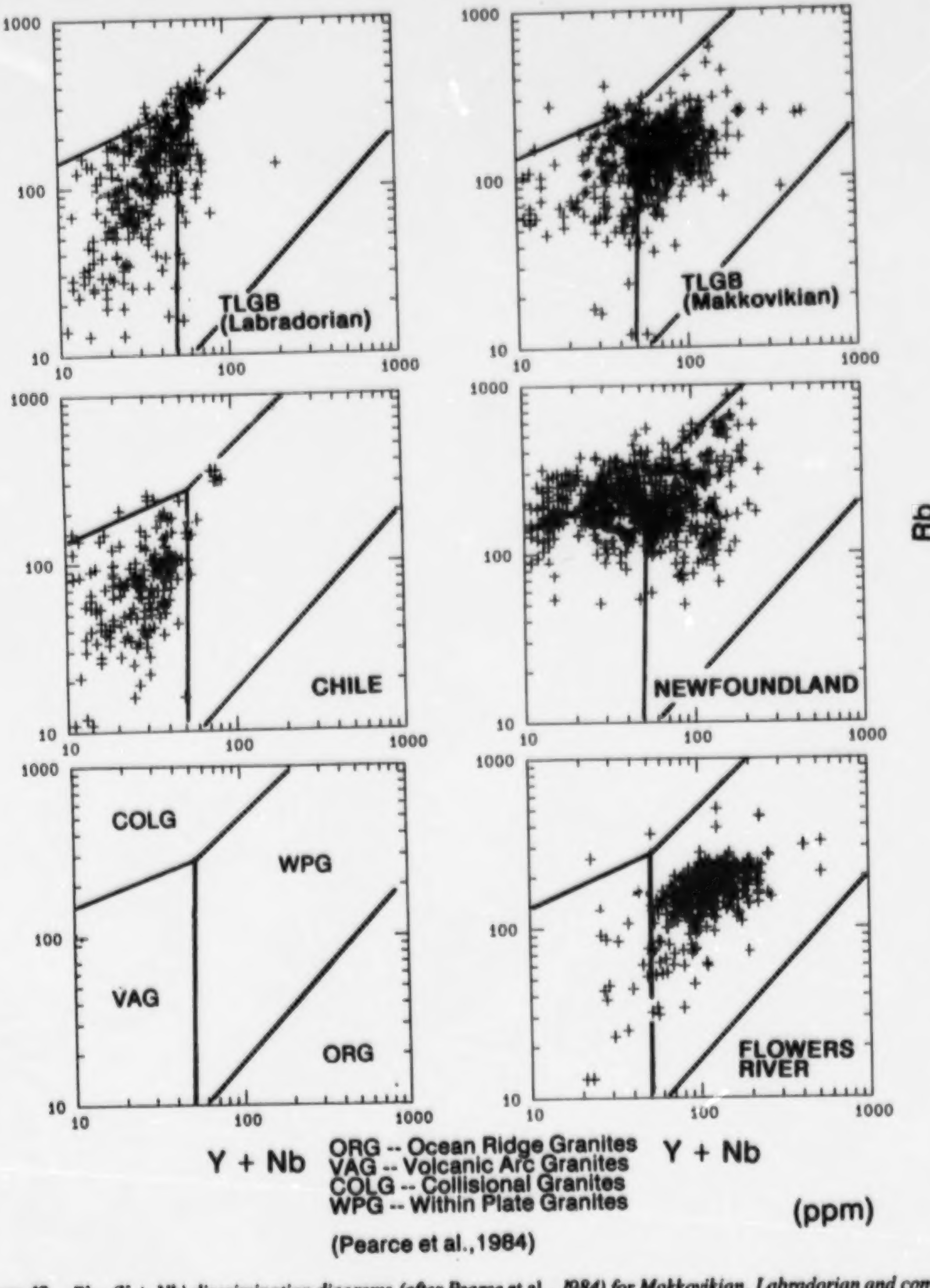


Figure 48. *Rb–(Y + Nb) discrimination diagrams (after Pearce* et al., *1984) for Makkovikian, Labradorian and comparative plutonic assemblages.*

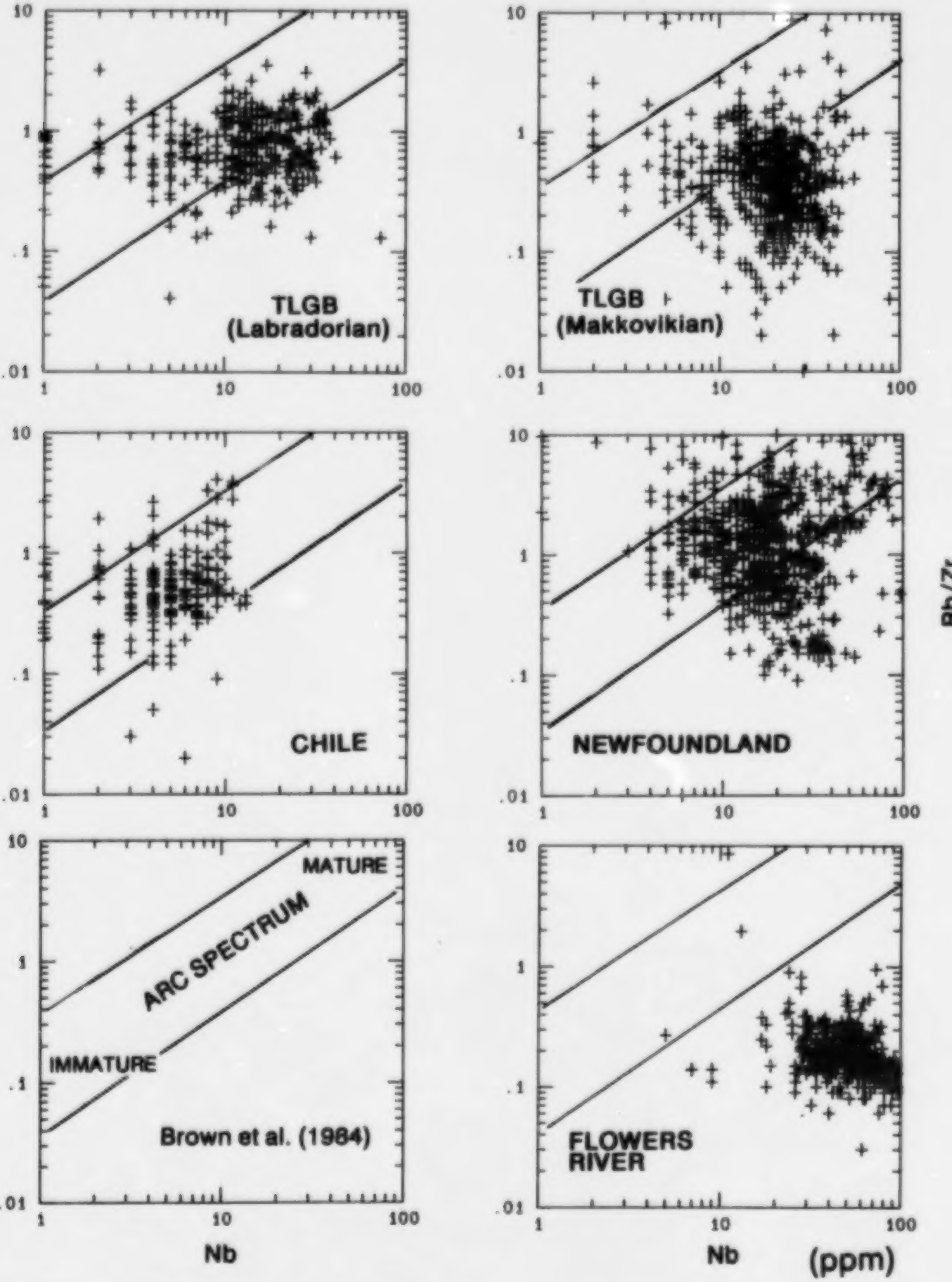


Figure 49. *Rb/Zr–Nb discrimination diagrams (after Brown et al., 1984) for Makkovikian, Labradorian and comparative plutonic assemblages.*

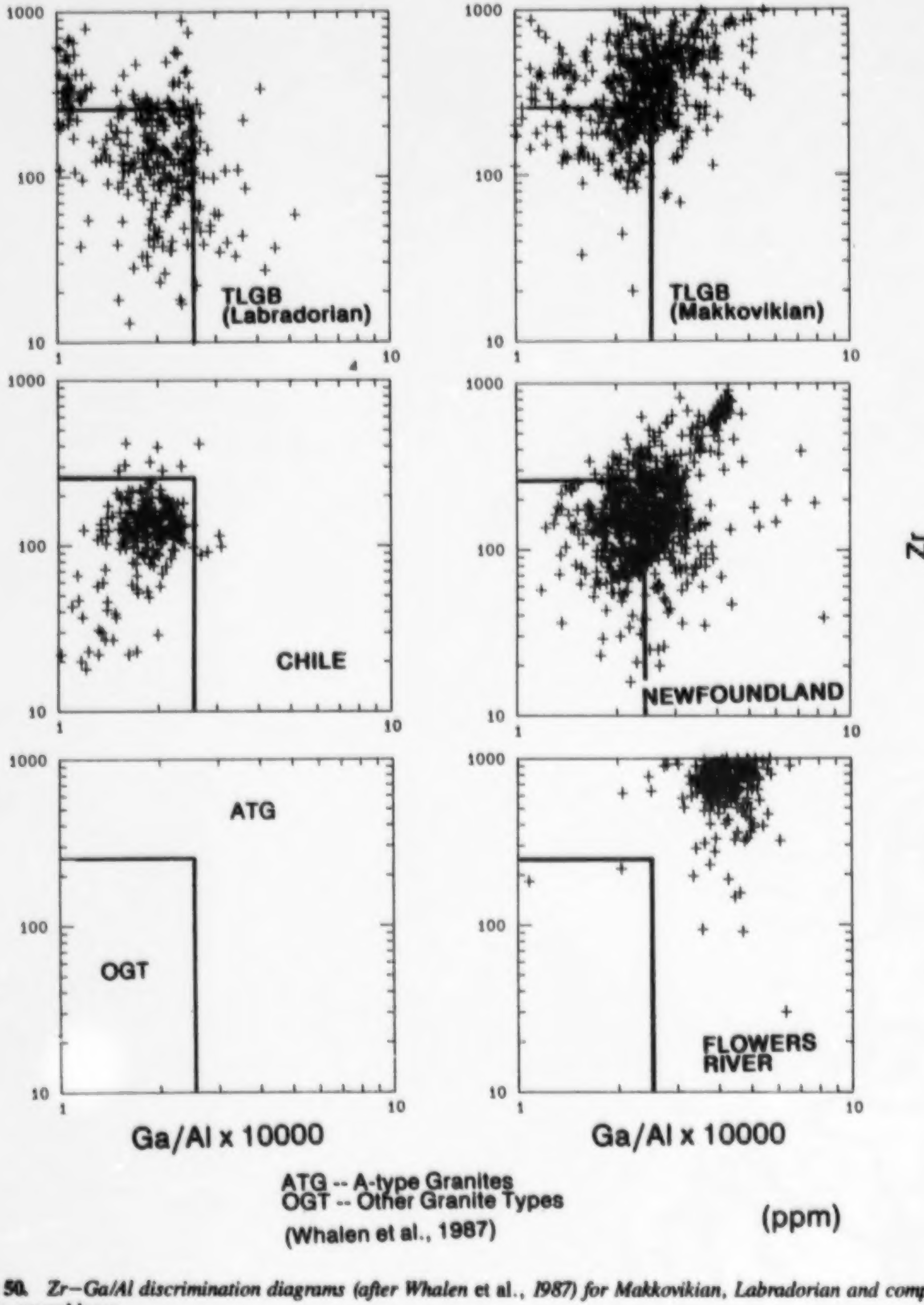


Figure 50. *Zr–Ga/Al discrimination diagrams (after Whalen* et al., *1987) for Makkovikian, Labradorian and comparative plutonic assemblages.*

Na_2O)/CaO−(Zr+Y+Nb+Ce) diagram (Figure 51) of Whalen *et al.* (1987) provides similar discrimination. As in the case of other discrimination diagrams, the partial similarity of the Makkovikian assemblage to post-orogenic granites from Newfoundland is striking.

Affinities of Labradorian Mafic-Intermediate Suites

The gabbroic to diorite−monzonite intrusions of the Labradorian assemblage cannot be interpreted using discrimination methods designed for granites. However, a number of discrimination methods have been proposed for elucidation of the tectonic setting of mafic volcanic rocks (e.g., Pearce and Cann, 1973).

In major-element terms, the mafic-intermediate Labradorian rocks (defined simply as those with < 60 percent SiO_2) correspond to shoshonitic (i.e., high-potash calc-alkaline basalts) compositions. This is illustrated by alkali-silica relationships (Figure 52), and also by comparison to mean analyses from various shoshonite suites compiled by Morrison (1980). In terms of their K_2O content, they lie in the less alkalic part of the shoshonite spectrum, and are transitional to calc-alkaline basalts.

In the well-known trace-element discrimination diagrams of Pearce and Cann (1973), Labradorian mafic-intermediate rocks lie mostly in the low-K tholeiite (LKT) and calc-alkaline-basalt (CAB) fields, with minor overlap into the within-plate-basalt (WPB) field (Figure 52).

COMPARISONS WITH SPECIALIZED GRANITE SUITES

One of the objectives of this project was to assess the extent and possible significance of so-called 'specialized granites' in the eastern Central Mineral Belt. In this section, the characteristics of such granites are summarized, and units from all three plutonic assemblages are assessed in a comparative sense.

Characteristics of Specialized Granites

Considerable efforts have been devoted to developing methods to distinguish granites that are mineralized (i.e., 'specialized' granites) from the greater population of barren granites. A number of absolute and relative characteristics have been suggested for the recognition of specialized granites (e.g., Tishendorf, 1977; Strong, 1981, 1988; Isihara, 1981; Ramsay, 1986). As will become apparent when compositions of selected specialized suites are listed in tabular form below, such rocks show extreme variations. Accordingly, an emphasis on relative characteristics, against backgrounds defined by 'average' granitic compositions for the area(s) in question, is preferred in this assessment. Some of the more important features of specialized granites are listed below.

1. High SiO_2 contents, generally 71 percent or greater, coupled with extreme depletion of MgO, CaO and FeO^t. Absolute limits are hard to place on the latter, but (MgO+CaO) < 1.5 percent and FeO^t < 1.5 percent appear to be upper limits in many areas.

2. Enrichment in a variety of incompatible or 'lithophile' trace elements, e.g., F, Rb, U, Th, Cs, Be; some granite associations may also display enrichment in HFS elements such as Zr, Y, Nb, and in REE. Absolute limits are very difficult to place on these criteria, as trace-element signatures vary widely in granophile mineral provinces, and absolute enrichment may depend on the local background, as defined by the larger population of barren granitoid rocks in a specific area. These characteristics appear to be a measure of the degree of fractionation that magmas have undergone, and final concentrations are dependent on the initial concentration(s) of the elements in question.

3. Extreme depletion of Sr, Ba, V and other compatible trace elements, coupled with low K/Rb ratios and high Rb/Sr ratios. Low Sr and Ba are a consequence of feldspar fractionation; as this is usually a late event in crystallization history, concentrations of these elements are dependant upon initial concentrations of Ba and Sr, and (most importantly) upon earlier fractionation history. Both elements behave incompatibly during fractionation of mafic minerals (e.g., pyroxene, amphibole), and may be concentrated prior to removal of feldspars. This tendency is illustrated by the curved Ba−SiO_2 trend shown by the Mount Benedict Intrusive Suite. V (and other 'siderophile' trace elements) tend to be uniformly low in specialized granites.

4. Variable enrichment in 'ore elements', e.g., Sn, W, Mo, etc. It should be emphasized that this is by no means a universal characteristic of specialized granites, as some suites are almost indistinguishable from barren granites in these terms. Also, these elements are commonly present in granites at levels that may be too low to permit separation of anomalous populations from background noise using common analytical techniques.

5. Disorganization of trace-element behaviour, as shown by extreme variations (particularly amongst incompatible elements), and a lack of expected correlations between major- and trace-element patterns. This may reflect the operation of processes such as thermogravitational diffusion (e.g., Hildreth, 1986) or convective fractionation (Rice, 1986) in concert with crystal fractionation, or the effects of syn- or post-crystallization hydrothermal alteration processes.

6. Evidence of high-level intrusion and high-volatile contents, e.g., miarolitic cavities, hydrothermal

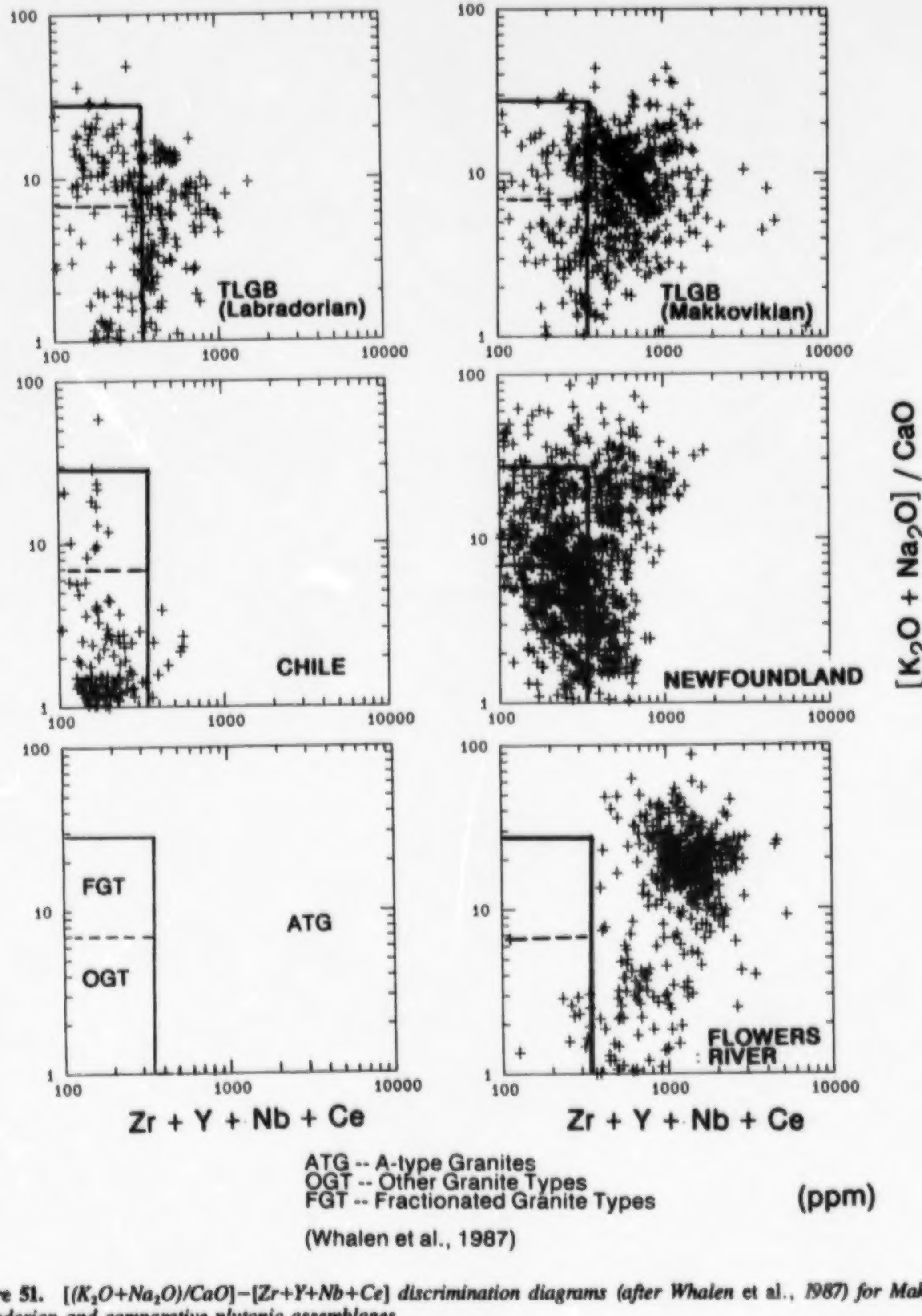


Figure 51. *[(K_2O+Na_2O)/CaO]–[Zr+Y+Nb+Ce] discrimination diagrams (after Whalen* et al., *1987) for Makkovikian, Labradorian and comparative plutonic assemblages.*

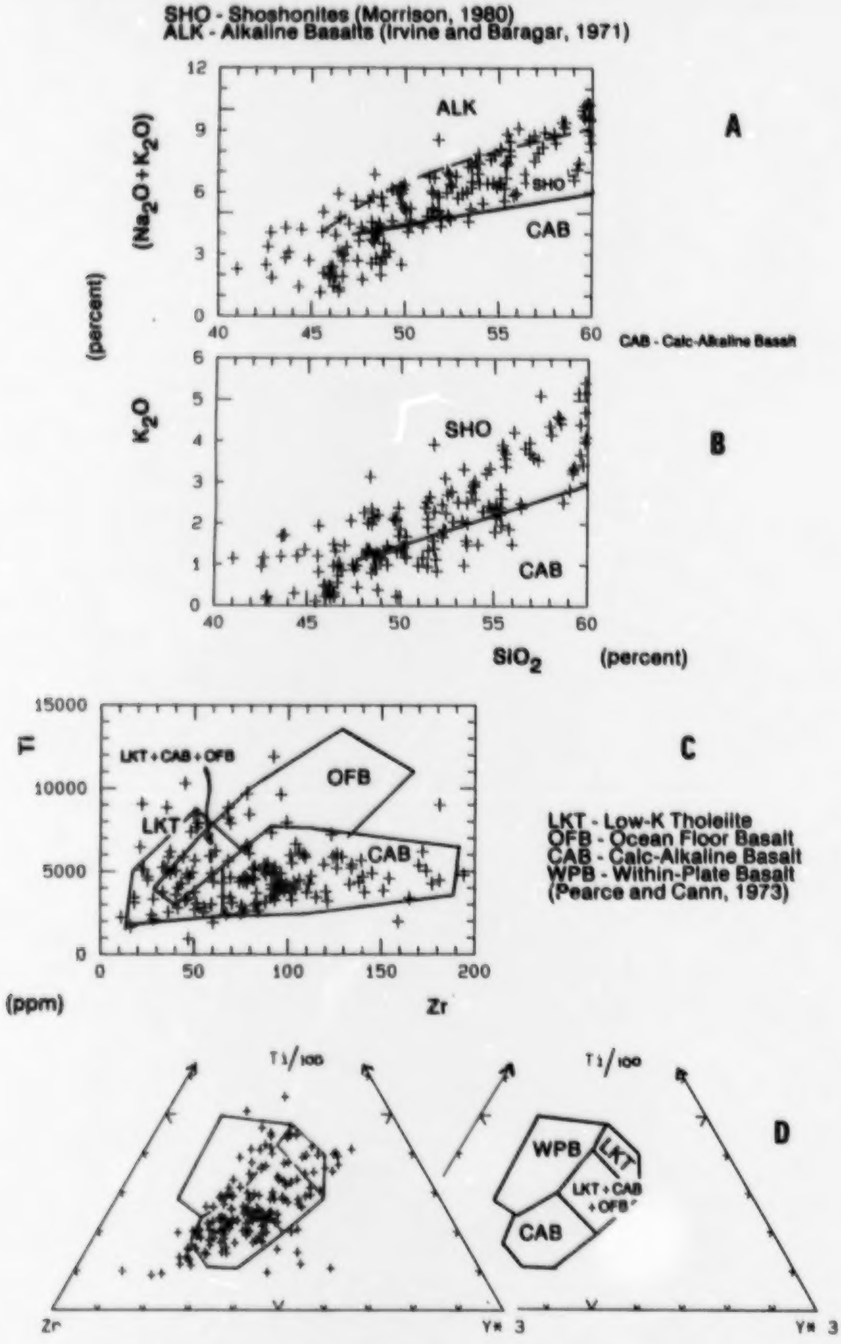


Figure 52. *Characteristics of Labradorian mafic and intermediate intrusive rocks. a) $(Na_2O+K_2O)-SiO_2$ diagram. b) K_2O-SiO_2 diagram. Field boundaries from Irvine and Baragar (1971) and Morrison (1980). c) Ti–Zr diagram. d) Ti/100–Zr–Y x 3 diagram. Field boundaries from Pearce and Cann (1973).*

breccia veinlets indicative of volatile exsolution (commonly termed 'tuffisite breccias') and alteration of minerals (e.g., kaolinization or albitization of K-feldspar, chloritization of biotite). Abundant pegmatite or coupled pegmatite–aplite bodies are also indicative of such environments.

7. Direct association with mineralization, either as a host rock (endocontact mineralization) or a spatial

association with epigenetic mineralization in surrounding country rocks (exocontact mineralization). Naturally, this final criterion is the most powerful definition of a specialized granite intrusion.

Geochemical Features of Granitoid Units Relative to 'Regional Average' Compositions

Table 12 lists the average compositions of a number of granitic (*ss*) units from both Makkovikian and Labradorian plutonic assemblages. In order to assess their characteristics relative to regional backgrounds, 'mean compositions' for syntectonic Makkovikian, posttectonic Makkovikian and Labradorian assemblages are also listed. These are calculated for all samples with SiO_2 contents of >60 percent, in order to screen out rocks of mafic and intermediate composition. The averages for the two subdivisions of the Makkovikian assemblage are closely similar, as might be expected from previous discussion; the Labradorian average differs principally in its lower average Zr, Y, Nb and REE abundances, as discussed above.

Syntectonic Makkovikian Granites

Amongst the syntectonic Makkovikian association, only the Kennedy Mountain Intrusive Suite and the Pitre Lake granite have major-element compositions that are significantly more evolved than the regional averages; the Melody Granite is close to the regional average. The individual units within the Kennedy Mountain Intrusive Suite that display the most evolved compositions are the Kennedy Mountain granite itself (SiO_2= 75.05 percent) and the Cross Lake granite (SiO_2= 74.49 percent) (see Table 4 for details). In terms of trace elements, the Kennedy Mountain Intrusive Suite displays slight enrichment in F, Zn, Zr, Y, Nb, La, Ce and Th, and depletion in Ba and Sr, relative to regional averages. Its Rb content is similar to the regional average.

The Pitre Lake granite displays very significant trace element enrichment and depletion patterns. It is particularly notable for its high Li, F, Rb, Y, Pb, Th and U, and its extreme depletion in Ba and Sr. Such features are generally consistent with its postulated origin as an anatectic derivative of metasedimentary rocks.

Posttectonic Makkovikian Granites

In the posttectonic Makkovikian group, the Strawberry Intrusive Suite average major-element composition is only slightly more evolved than the regional average; however, the Cape Strawberry granite itself shows much more significant fractionation. In trace-element terms, these suites are significantly enriched in F, Li, Th and U, somewhat enriched in Rb, and depleted in Ba and Sr relative to regional averages. Levels of Zr and other HFS elements, and REE are close to the regional averages.

The Lanceground Intrusive Suite has a composition that resembles that of the Strawberry Intrusive Suite in most respects, but it also shows significant Zr, Y, Hf, La and Ce enrichment relative to average compositions. The Big River Granite has a major- and trace-element composition that is similar to, or less evolved than, the regional average.

Labradorian Granites

In the Labradorian association, the syenite and granite unit of the Mount Benedict Intrusive Suite is similar in major-element composition to the regional average. However, it displays very significant trace-element enrichment and depletion. It is enriched in F, Rb, Zr, Cs, Sn, Th and U, and slightly depleted in Ba and Sr.

The Monkey Hill Intrusive Suite has an evolved major-element composition relative to the regional average, but its trace-element signature resembles the regional average, or is less evolved (e.g., U and Th). The Round Pond granite, which is spatially associated with mineralization, shows extreme depletion in Li, Ba, Sr, Zn, La and Ce, which may be partly of hydrothermal origin (MacDougall, 1988).

The Witchdoctor and Burnt Lake granites have evolved major-element compositions, but, excluding F depletion, show no clear trace-element enrichment or depletion compared to regional averages.

Geochemical Features of Granitoid Units Relative to Other Specialized Granite Assemblages

Tables 13, 14 and 15 presents a compilation of geochemical data from a number of granitoid suites whose relationship to various types of metallic mineralization is well established. These are subdivided into three groups.

Peraluminous Specialized Granites

Table 13 lists analyses of peraluminous, commonly muscovite-bearing, granites that are associated with the metal association Sn−W (± Pb, Zn, Mo, B). These include the South Mountain Batholith of Nova Scotia (Clarke *et al.*, 1985), the Cornubian batholith of southwest England (Alderton *et al.*, 1980; Manning and Pichavant, 1988; Hall, 1990), Sn-bearing granites in Alaska (Hudson and Arth, 1983), so-called 'plumasitic' granites in Saudi Arabia (Ramsay, 1986), Sn-bearing granites of the Herberton area, Queensland (Pollard, 1988) and Thailand (Manning and Pichavant, 1988). The average composition of 'S-type' peraluminous granites, as provided by Whalen *et al.* (1987), based on data from Australia, is also included for reference. In terms of tectonic setting, such suites are generally inferred to develop in collisional or megashear environments, by anatexis of crustal materials (e.g., Isihara, 1981; Strong, 1988).

Most of these specialized suites are characterized by highly anomalous trace-element patterns; strong enrichments

Table 12. Average compositions of selected granitoid units compared to the 'regional average' compositions of syntectonic Makkovikian, posttectonic Makkovikian and Labradorian granitoid rocks

ANALYSES	1		2		3		4		5		6		7	
n[1]	108		31		4		197		55		82		79	
n[2]	22		19				142		47		66		13	
(Wt%)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
SiO_2	73.74	3.09	72.27	3.26	76.18	0.38	71.29	4.71	72.81	3.56	72.12	2.93	70.11	5.15
TiO_2	0.28	0.18	0.35	0.21	0.05	0.02	0.31	0.27	0.21	0.11	0.32	0.19	0.39	0.22
Al_2O_3	12.65	1.13	13.50	1.10	12.87	0.23	13.68	1.55	13.20	1.50	13.22	1.34	14.43	1.74
Fe_2O_3	1.29	0.67	0.97	0.68	0.36	0.24	1.05	0.74	1.14	0.80	1.21	0.57	1.16	0.55
FeO	1.34	1.13	1.74	1.12	0.43	0.25	1.68	1.47	1.23	0.81	1.44	0.87	1.49	0.97
MnO	0.06	0.03	0.04	0.02	0.03	0.01	0.06	0.06	0.05	0.05	0.06	0.04	0.06	0.04
MgO	0.19	0.24	0.41	0.37	0.02	0.01	0.36	0.50	0.27	0.55	0.18	0.17	0.50	0.84
CaO	0.84	0.61	1.18	0.72	0.47	0.17	1.14	1.04	0.91	1.17	0.88	0.47	1.36	1.20
Na_2O	4.40	1.08	3.80	0.76	4.31	0.26	4.09	0.86	4.21	1.26	3.97	0.61	4.28	0.75
K_2O	4.29	1.56	4.59	0.99	4.32	0.24	5.12	1.10	4.97	1.33	5.47	0.90	5.11	1.01
P_2O_5	0.05	0.05	0.09	0.07	0.02	0.01	0.07	0.09	0.04	0.03	0.04	0.04	0.10	0.08
LOI	0.45	0.21	0.70	0.34	0.62	0.04	0.67	0.37	0.67	0.60	0.53	0.20	0.58	0.29
TOTAL	99.58		99.63		99.66		99.52		99.71		99.44		99.57	
(ppm)	Trace elements													
Li	14.6	11.3	18.1	13.5	162.5	98.0	25.0	23.5	26.5	23.8	13.9	11.7	14.8	6.2
F	1014.0	847.4	613.7	481.2	2660.5	746.6	1420.0	1141	1541.1	1021	1244.6	935.7	688.5	462.5
Sc	1.3	0.9	2.9	1.6			3.1	4.1	1.9	1.7	3.8	5.3	2.4	0.9
V	15.6	12.7	24.3	17.7	13.0	2.4	23.3	29.2	20.4	41.9	12.8	7.7	21.5	17.1
Cr	5.0	3.8	3.7	3.5	4.5	1.7	5.1	6.5	6.3	7.9	3.7	2.9	4.8	13.7
Ni	1.4	1.2	1.7	1.5	1.5	0.6	2.2	3.9	2.6	5.8	1.5	1.8	2.6	7.9
Cu	3.8	3.8	7.3	15.1	2.0	1.2	9.3	38.4	11.3	44.8	6.0	9.2	6.3	6.1
Zn	81.8	53.3	45.0	27.9	61.3	23.9	75.1	69.6	84.3	82.3	89.6	59.6	54.8	42.8
Ga	16.6	7.3	18.3	2.2	16.5	7.2	16.9	8.6	17.6	10.2	21.4	10.0	15.2	5.2
Rb	134.6	64.9	122.0	36.0	411.5	163.4	178.4	65.0	176.1	62.1	172.5	44.1	127.8	51.8
Sr	62.0	75.6	106.8	89.9	7.8	2.2	111.7	130.2	77.5	71.8	61.2	65.8	160.7	151.6
Y	72.2	30.5	45.2	17.8	125.0	32.8	55.4	43.8	64.3	46.9	74.4	32.8	42.5	17.2
Zr	388.7	146.8	361.9	162.9	114.3	23.1	491.5	558.5	471.5	418.2	675.7	439.3	368.8	210.3
Nb	28.3	13.8	20.6	5.6	36.5	11.6	26.0	21.0	29.9	33.4	29.3	11.1	19.1	7.2
Mo	3.6	1.8	3.4	1.0	2.0	0.0	4.3	7.7	3.7	2.0	4.3	2.3	3.7	1.2
Sn	3.3	2.1	4.4	3.7			5.8	9.9	5.0	3.2	4.0	2.6	2.7	2.7
Cs	0.7	0.4	2.2	1.4			1.2	1.0	1.1	0.7	1.1	0.7	0.7	0.6
Ba	433.8	433.5	827.6	481.8	42.0	38.2	501.9	382.6	344.9	264.0	329.6	260.1	660.8	482.6
La	78.9	35.2	85.2	38.2	12.3	4.3	90.7	111.7	75.4	46.8	122.8	62.6	63.1	30.2
Ce	163.1	66.9	171.4	66.8	32.5	9.9	178.7	197.0	156.9	84.8	247.2	121.1	126.8	59.2
Sm	12.4	3.7	13.8	5.0			13.1	10.4	12.8	6.4	20.8	9.8	10.4	3.9
Yb	7.2	3.6	5.2	2.5			6.6	4.7	7.6	5.1	8.8	4.3	4.2	2.0
Hf	12.2	3.4	10.8	4.1			13.3	13.3	13.3	7.5	19.1	10.3	10.1	3.0
Pb	19.3	10.6	14.1	7.5	61.5	1.3	37.3	205.3	23.3	9.6	24.5	13.5	17.6	11.2
Th	15.7	9.7	12.1	6.1	23.3	18.2	18.3	20.5	23.4	28.3	18.9	8.0	13.0	9.6
U	4.8	2.9	3.7	2.0	8.6	8.2	5.8	7.0	8.0	11.9	5.5	2.3	4.5	2.6

KEY TO ANALYSES:

1 Kennedy Mountain Intrusive Suite (all data)
2 Melody Granite
3 Pitre Lake granite
4 Strawberry Intrusive Suite (all data)
5 Cape Strawberry granite
6 Lanceground Intrusive Suite (all data)
7 Big River Granite (all data)
n[1] Number of analyses for all elements except those listed below
n[2] Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 12. *(Continued)*

8		9		10		11		12		13		14	
67		70		4		34		201		431		267	
39		57		2		29		50		235		158	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
70.69	3.31	73.50	4.42	75.69	1.69	73.24	3.22	72.28	4.17	70.44	4.48	70.61	4.31
0.30	0.18	0.14	0.12	0.04	0.01	0.15	0.11	0.34	0.24	0.38	0.25	0.31	0.22
14.39	1.06	13.49	1.18	12.75	0.21	13.98	1.49	13.45	1.61	14.02	1.63	14.51	1.44
0.97	0.40	1.08	3.23	0.42	0.07	0.61	0.45	1.19	0.69	1.14	0.63	0.94	0.52
1.09	0.65	0.70	1.56	0.12	0.08	0.62	0.31	1.48	1.11	1.81	1.24	1.23	0.93
0.05	0.02	0.05	0.04	0.01	0.00	0.04	0.01	0.05	0.03	0.07	0.05	0.06	0.03
0.38	0.27	0.21	0.24	0.06	0.02	0.18	0.15	0.37	0.43	0.34	0.34	0.47	0.42
0.97	0.49	0.76	0.44	0.38	0.10	0.78	0.36	1.21	0.95	1.18	0.75	1.25	0.82
4.28	0.43	4.26	1.07	4.34	0.28	4.27	1.11	4.30	0.94	4.20	0.76	4.27	0.81
5.58	0.51	4.72	1.22	4.33	0.44	4.98	0.87	4.28	1.36	5.30	0.96	5.15	0.89
0.05	0.06	0.03	0.03	0.01	0.00	0.02	0.03	0.08	0.08	0.08	0.08	0.08	0.08
0.75	0.11	0.58	0.27	0.50	0.11	0.50	0.13	0.55	0.28	0.58	0.29	0.68	0.21
99.50		99.48		98.65		99.37		99.57		99.54		99.52	
25.3	11.0	20.5	13.6	5.5	1.0	20.7	19.8	19.3	27.3	19.0	16.7	24.6	13.9
1240.5	617.4	511.7	436.6	258.3	201.4	177.7	120.6	899.6	782.8	1081.3	919.7	822.1	599.7
2.9	1.7	1.4	1.2	0.3	0.0	1.9	1.2	2.7	2.7	3.6	4.2	2.8	2.3
23.1	13.1	17.4	18.1	12.0	5.3	14.6	6.8	23.6	21.5	19.9	20.0	26.1	19.7
6.5	3.8	4.0	6.4	2.0	0.8	3.5	3.8	4.6	3.5	4.1	4.9	5.9	6.3
1.9	1.7	1.4	1.3	1.0	0.0	1.7	2.1	1.5	1.3	1.7	2.7	1.9	2.3
10.1	8.8	9.2	20.2	11.8	7.4	3.8	3.7	4.9	7.1	7.3	26.1	9.4	13.3
39.9	14.0	34.9	30.5	9.0	3.2	28.8	10.9	70.0	46.2	76.6	56.1	40.5	18.8
8.6	2.1	12.0	6.6	11.3	2.6	11.7	5.8	17.0	6.1	18.0	8.2	10.7	4.4
315.3	81.3	181.7	71.7	184.8	38.9	191.1	68.2	135.7	77.1	156.7	62.6	219.7	94.7
126.8	108.3	134.5	210.4	29.0	16.8	87.1	75.8	137.2	167.2	112.9	105.8	175.7	167.2
27.8	7.6	26.5	23.0	11.5	1.3	25.3	20.2	57.1	34.8	54.7	32.9	27.9	15.4
345.0	140.0	160.1	99.3	100.3	31.9	185.6	172.3	329.3	162.2	513.4	420.4	273.6	173.4
29.0	8.6	17.2	8.5	17.0	9.7	20.8	13.6	23.0	13.5	24.4	15.5	21.0	10.0
4.3	2.7	84.5	578.7	2.3	1.0	28.1	142.9	3.6	1.8	3.8	1.9	28.2	301.0
7.2	4.2	2.9	2.3	1.0	0.0	2.4	2.1	3.6	3.0	4.9	8.0	4.4	3.8
9.0	4.3	2.2	2.1	0.5	0.0	1.9	1.3	1.3	1.2	1.1	1.0	5.2	4.8
381.9	352.6	391.2	360.5	47.0	21.4	519.0	675.5	638.3	530.2	571.9	489.8	585.5	573.1
56.3	22.9	22.1	21.4	3.8	3.5	30.9	22.3	67.5	37.9	86.8	61.0	42.4	24.2
114.0	43.7	45.4	43.8	4.0	4.8	63.2	45.7	137.3	74.2	173.6	115.6	86.7	49.1
6.9	1.7	4.4	4.0	1.0	0.4	4.2	1.9	12.7	4.1	14.6	8.2	5.9	3.3
4.5	0.9	3.9	3.6	2.5	0.0	2.8	0.6	6.1	3.3	6.7	4.2	3.8	2.3
9.9	3.1	5.6	3.0	3.0	0.0	5.6	1.5	11.3	3.7	14.0	8.3	8.1	6.6
23.4	8.0	22.6	9.2	13.0	5.4	26.8	11.5	18.8	11.3	27.7	139.1	21.5	8.9
37.5	13.8	13.6	8.5	7.0	2.9	19.1	9.2	14.0	9.8	15.4	15.3	22.2	14.5
10.4	4.4	6.0	5.1	5.0	2.7	7.4	5.0	4.5	2.9	5.0	5.1	7.1	4.7

KEY TO ANALYSES:

- 8 Mount Benedict Intrusive Suite (syenite-granite)
- 9 Monkey Hill Intrusive Suite (all data)
- 10 Round Pond Granite
- 11 Witchdoctor and Burnt Lake granites
- 12 Average of Syntectonic Makkovikian granites
- 13 Average of Posttectonic Makkovikian granites
- 14 Average of Labradorian granites
- n[1] Number of analyses for all elements except those listed below
- n[2] Number of analyses for Sc, Sn, Cs, Sm, Yb and Hf

Table 13. Average and representative compositions of specialized granites of peraluminous affinity

UNIT	1	2	3	4	5	6	7	8	9	10	11	12
N	30	94	14	5	5	9	n/a	n/a	–	4	578	205
(Wt%)	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Repr	Mean	Mean	Mean
SiO_2	74.06	75.84	73.40	71.44	71.67	75.80	75.54	75.41	76.33	71.83	70.27	73.39
TiO_2	0.20	0.13	0.28	0.24	0.03	0.11	0.16	0.10	0.06	0.35	0.48	0.28
Al_2O_3	13.62	12.65	13.88	14.98	14.88	13.02	12.84	12.82	11.96	14.14	14.10	13.45
Fe_2O_3	0.16		*2.08	1.06	0.43	0.38	1.13	0.77	0.22	0.36	0.56	0.36
FeO	1.51	*1.21		0.85	0.53	0.64	0.38	0.59	0.99	1.58	2.87	1.73
MnO	0.04	0.04	0.04	0.04	0.09	0.04	0.06	0.04	0.03	0.05	0.06	0.04
MgO	0.28	0.18	0.42	0.44	0.11	0.13	0.11	0.09	0.03	0.56	1.42	0.58
CaO	0.59	0.67	0.78	0.73	0.66	0.78	0.53	0.62	0.68	1.40	2.03	1.28
Na_2O	3.45	3.41	2.52	2.72	4.15	3.54	4.20	4.19	2.90	2.52	2.41	2.81
K_2O	4.72	4.08	4.89	5.46	4.31	4.80	4.52	4.51	5.06	6.30	3.96	4.56
P_2O_5	0.14	0.11	0.21	0.24	0.78	0.04	0.03	0.02	0.01	0.14	0.15	0.14
LOI	0.80	0.76				0.33	0.47	0.52	1.45	0.88		
TOTAL	99.57	97.87	96.42	98.20	97.64	99.61	99.97	99.68	99.72	100.11	98.31	98.62
	(* total Fe as FeO or Fe_2O_3)											
(ppm)	Trace elements											
Li	277.0	146.0	251.0	95.0	4400.0		35.0	184.0	50.0	240.0		
F	1500.0	3300.0			>10000	3800.0	773.0	2342.0	4900.0	2000.0		
Sc	3.7		4.0			2.5	3.0	4.0			12.0	8.0
V			20.0				13.0	9.0			56.0	23.0
Cr			6.0			2.8						
Ni			19.0				4.0	6.0			13.0	4.0
Cu	8.0	7.0	11.0				7.0	5.0			11.0	4.0
Zn	60.0	43.0	43.0				60.0	83.0			62.0	44.0
Ga									19.2		17.0	17.0
Rb	388.0	700.0		465.0	1434.0	811.0	151.0	386.0	680.0	487.0	217.0	277.0
Sr	25.0	31.0	76.0	86.0	46.0	8.0	47.0	38.0	13.0	92.0	120.0	81.0
Y			18.0				39.0	62.0	121.0		32.0	33.0
Zr			132.0	86.0		25.0	195.0	211.0	125.0		165.0	136.0
Nb			16.0				31.0	56.0	19.0		12.0	13.0
Mo	2.0	2.0					2.0	4.0				
Sn	22.0	50.0	23.0		57.0		< 12.0	16.0	23.0			
Cs	23.6					41.0						
Ba	181.0	73.0	183.0		14.0	39.0	182.0	79.0	30.0	265.0	468.0	388.0
La			27.0			24.0	35.0	41.0				
Ce			58.0			62.0	75.0	95.0			64.0	53.0
Sm												
Yb						18.0						
Hf	3.0					6.0						
Pb		7.0					16.0	32.0	22.0		27.0	28.0
Th	10.6	25.0		21.0		34.1	20.0	31.0	68.0		18.0	18.0
U		23.0				21.1	4.0	8.0	21.0		4.0	6.0

KEY TO ANALYSES (Mean = average composition, Repr = 'representative' composition)

1. South Mountain Batholith, NS–monzogranites (Clarke *et al.*, 1985)
2. South Mountain Batholith, NS–Sn-specialized granite (Clarke *et al.*, 1985)
3. Cornubian Granites (Hall, 1990)
4. Cornish Granites (Alderton, 1980)
5. Topaz-bearing granites, Cornwall (Manning and Pichavant, 1988)
6. Tin-mineralized granites, Alaska (Hudson and Arth, 1983)
7. 'Plumasitic' precursor granites, Saudi Arabia (Ramsay, 1986)
8. 'Plumasitic', Sn–W specialized granites, Saudi Arabia (Ramsay, 1986)
9. Emuford district, Herberton Tinfield, Australia (Pollard, 1988)
10. Tin Granite, Thailand (Manning and Pichavant, 1988)
11. 'Average' S-type granite, Southern Australia (Whalen *et al.*, 1987)
12. 'Felsic' S-type Granites, Southeastern Australia (Whalen *et al.*, 1987)

Table 14. Average and representative compositions of specialized granites of metaluminous-peralkaline affinity

ANALYSES	1	2	3	4	5	6	7	8	9	10	11
N	n/a	n/a	n/a	n/a	n/a	n/a	22	102	75	367	42
	(* Total Fe as FeO or Fe_2O_3)										
(Wt%)	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
SiO_2	74.52	76.80	76.50	73.45	73.81	74.18	76.60	76.16	74.56	72.52	73.39
TiO_2	0.05	0.03	0.14	0.07	0.30	0.32	0.18	0.19	0.26	0.40	0.29
Al_2O_3	13.70	11.60	11.06	11.67	11.81	11.1	11.00	11.05	12.41	11.78	12.88
Fe_2O_3	1.23	1.63	1.63	1.96	2.85	2.86	1.88	1.27	0.90	2.49	0.90
FeO	0.29	0.80	0.80	0.91	1.05	1.21	0.45	0.84	1.45	1.93	1.69
MnO	0.01	0.01	0.01	0.23	0.09	0.09	0.03	0.03	0.06	0.06	0.06
MgO	0.07	0.05	0.05	0.03	0.09	0.08	0.05	0.37	0.19	0.16	0.30
CaO	0.50	0.25	0.25	0.54	0.56	0.5	0.09	0.57	0.62	0.75	1.07
Na_2O	4.20	3.77	3.77	5.56	4.20	4.25	3.75	3.51	4.15	4.20	3.49
K_2O	4.05	4.97	4.97	3.93	4.59	4.61	4.57	4.57	4.68	5.07	4.61
P_2O_5	0.01	0.01	0.01	0.01	0.05	0.04	0.01	0.02	0.03	0.05	0.08
LOI					0.54	0.44	0.49	0.50	0.58	0.58	0.96
TOTAL	98.63	99.92	99.19	98.36	99.94	99.68	99.10	99.08	99.89	99.99	99.72
(ppm)	Trace elements										
Li	180.0	220.0	118.0	750.0	21.0	51.0	8.8			39.8	
F	4860.0	4900.0	4850.0	12000.0	844.0	1572.0	79.0	1670.0	797.0	6.1	
Sc					3.0	3.0			2.2		10.9
V					10.0	10.0	6.0		6.2		9.3
Cr							2.0				
Ni					8.0	13.0	1.0		1.0	1.2	2.1
Cu					10.0	13.0	12.0	4.8	2.1	6.5	4.9
Zn	240.0	160.0	240.0	496.0	120.0	137.0	115.0	60.2	91.6	135.4	94.8
Ga	48.0	48.0	42.0	65.0			27.0		23.5	27.6	21.7
Rb	800.0	720.0	430.0	1500.0	110.0	169.0	193.0	276.4	140.3	179.5	188.2
Sr	3.0	11.0	36.0	20.0	38.0	20.0	11.0	29.4	33.3	26.5	96.9
Y	211.0	210.0	205.0	560.0	84.0	91.0	150.0		77.4	70.3	70.5
Zr	200.0	100.0	680.0	2080.0	747.0	765.0	690.0	574.7	522.2	1004.9	324.6
Nb	150.0	160.0	160.0	1080.0	60.0	62.0	65.0		28.8	55.9	26.1
Mo											
Sn	26.0	73.0	36.0	120.0	< 12.0	10.0	5.2				
Cs											
Ba	80.0	54.0	36.0	20.0	265.0	99.0	73.0	92.1	328.2	246.5	546.2
La					77.0	71.0	34.0			140.9	
Ce					181.0	182.0	200.0		139.2	289.1	125.8
Sm											
Yb											
Hf											
Pb	70.0	45.0	38.0	42.0	15.0	14.0	18.0		19.7	26.3	27.2
Th	61.0	50.0	55.0	118.0	15.0	14.0	31.0		21.6	17.7	23.6
U					3.0	4.0	6.2	8.5	5.1	2.9	4.7

KEY TO ANALYSES (mean = average composition)

1 Ore-related biotite granite, Nigerian younger granites (Imeokparia, 1988)
2 Ore-related biotite granite, Nigerian younger granites (Imeokparia, 1988)
3 Peralkaline granite, Nigerian younger granites (Imeokparia, 1988)
4 Peralkaline granite, Nigerian younger granites (Imeokparia, 1988)
5 'Agpaitic' precursor granites, Saudi Arabia (Ramsay, 1986)
6 'Agpaitic' specialized granites, Saudi Arabia (Ramsay, 1986)
7 Peralkaline granite, Cross Hills Suite, Newfoundland (Saunders and Tuach, 1989)
8 Peralkaline granite, St. Lawrence, Newfoundland (NDNR; unpublished)
9 A-type granites, Topsails Intrusive Suite (Whalen *et al.*, 1987)
10 Peralkaline granites, Flowers River area, Labrador (NDNR; unpublished)
11 A-type granites, Lachlan Fold Belt, Australia (Whalen *et al.*, 1987)

Table 15. Average and representative compositions of specialized granites of metaluminous (subalkaline) affinity

ANALYSES	1	2	3	4	5	6	7	8	9	10	11	12
N	4	52	n/a	n/a	136	357	49	9	7	12	991	421
(* Total Fe as FeO or Fe_2O_3)												
(Wt%)	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
SiO_2	74.55	72.58	71.29	72.94	74.48	73.71	75.47	76.86	73.80	75.40	69.17	73.39
TiO_2	0.06	0.34	0.36	0.30	0.08	0.29	0.18	0.11	0.21	0.25	0.43	0.26
Al_2O_3	13.60	13.32	14.29	14.02	13.90	13.11	12.65	11.99	13.30	12.90	14.33	13.43
Fe_2O_3	0.84	0.76	1.36	1.21		0.53	0.33	0.39	0.84	*3.00	1.04	0.6
FeO	0.53	2.14	1.01	0.74	*0.93	1.09	0.90	0.55	0.62		2.29	1.32
MnO	0.04	0.04	0.05	0.06	0.02	0.05	0.03	0.04	0.05	0.09	0.07	0.05
MgO	0.02	0.25	0.50	0.42	0.05	0.45	0.16	0.10	0.30	0.20	1.42	0.55
CaO	0.85	1.17	1.65	1.39	0.75	0.92	0.49	0.33	0.85	0.90	3.20	1.71
Na_2O	3.26	2.65	4.04	4.14	3.48	3.45	3.77	3.52	3.45	4.50	3.13	3.33
K_2O	4.85	5.63	4.29	4.06	4.39	5	4.90	4.98	4.67	3.60	3.40	4.13
P_2O_5	0.06	0.08	0.11	0.09	0.44	0.06	0.03	0.01	0.05	0.03	0.11	0.07
LOI	0.50	0.65	0.62	0.58	0.63	0.83	0.71		0.77		0.71	
TOTAL	99.16	99.61	99.57	99.95	98.22	99.49	99.62	99.65	98.14	98.58	98.59	98.84
(ppm)	Trace elements											
Li	273.0	65.0	36.0	30.0	517.0	43.0	30.0	87.0		25.0		
F	10000.0	1029.0	653.0	4500.0	737.0	533.0	2016.0					
Sc			4.0	4.0							13.0	8.0
V			22.0	21.0		20.0	9.0	5.0		2.0	60.0	22.0
Cr										4.0		
Ni			12.0	4.0						3.0	7.0	2.0
Cu			9.0	15.0	31.0	3.0	2.0	2.0		2.0	9.0	4.0
Zn			48.0	42.0	86.0	16.0	20.0	12.0	28.0	82.0	49.0	35.0
Ga	80.0					17.0	18.0	21.0		24.0	16.0	16.0
Rb	965.0	393.0	135.0	113.0	769.0	274.0	263.0	556.0	145.0	129.0	151.0	194.0
Sr	40.0	71.0	248.0	196.0	38.0	112.0	47.0	11.0	175.0	62.0	247.0	143.0
Y			35.0	21.0		55.0	75.0	96.0		117.0	28.0	34.0
Zr	55.0	266.0	245.0	169.0		159.0	164.0	154.0	156.0	424.0	151.0	144.0
Nb	60.0		26.0	21.0		34.0	44.0	76.0		26.0	11.0	12.0
Mo			3.0	2.0		4.0	4.0	5.0		1.0		
Sn			8.0	<6	39.0	2.0	3.0	29.0		9.0		
Cs	77.0											
Ba	120.0	644.0	700.0	571.0	39.0	308.0	175.0	56.0		591.0	538.0	510.0
La			46.0	28.0								
Ce			112.0	54.0						128.0	64.0	68.0
Sm												
Yb												
Hf												
Pb			31.0	18.0		27.0	26.0	35.0		27.0	19.0	23.0
Th			15.0	10.0	5.0	40.0	32.0	65.0	23.0	14.0	18.0	22.0
U			2.0	2.0		5.0	7.0	14.0	9.0	4.0	4.0	5.0

KEY TO ANALYSES (Mean = average composition)

1 Topaz granite, Eurajoki Stock, Finland (Haapala, 1988)
2 Laitila rapakivi granite massif, Finland (Haapala, 1988)
3 'Calcic' specialized granites, Saudi Arabia (Ramsay, 1986)
4 'Calcic' precursor granites, Saudi Arabia (Ramsay, 1986)
5 Uranium-specialized granites, South Mountain Batholith, Nova Scotia (Clarke *et al.*, 1985)
6 Ackley high-silica granite suite, All data (Tuach *et al.*, 1986)
7 Mo-specialized granite, Ackley granite suite (Tuach *et al.*, 1986)
8 Sn-specialized granite, Ackley granite suite (Tuach *et al.*, 1986)
9 Mo-specialized quartz porphyry, Climax, Colorado (Hudson *et al.*, 1981)
10 W-specialized granite, Carrock Fell, Cumbria, England (O'Brien *et al.*, 1985)
11 I-type granites, Lachlan Fold Belt, Australia (Whalen *et al.*, 1987)
12 Felsic I-type granites, Lachlan Fold Belt, Australia (Whalen *et al.*, 1987)

in Li, Rb and Sn are particularly characteristic. Abundances of other trace elements, however, are highly variable, emphasizing that geochemical specialization is difficult to establish on absolute grounds. The only unit in the study area that displays analogous trace-element patterns is the syntectonic Pitre Lake granite, which compares well to several of the specialized suites. There is a general absence of strongly peraluminous granites in the study area, so deposits of this association appear unlikely.

Metaluminous–Peralkaline Specialized Granites

Table 14 lists average analyses from a number of metaluminous to peralkaline granite suites; these are associated with Zr–Y–REE deposits, Sn-Ta-Nb mineralization (Nigerian examples) and fluorite. These include the younger (Mesozoic) granites of Nigeria (Kinnaird and Bowden, 1987; Imeokparia, 1988), 'agpaitic' specialized granites in Saudi Arabia (Ramsay, 1986), and various peralkaline suites in Newfoundland and Labrador (Whalen *et al.*, 1987; Saunders and Tuach, 1989; unpublished Geological Survey data). Mineralization is not known to occur within the Topsails Intrusive Suite, although it is considered to have potential (Miller, 1989). The average composition of so-called 'A-type' granites, based on data from Australia (Whalen *et al.*, 1987), is also shown for reference purposes. A-type granites are not invariably peralkaline, but many apparently evolve to such compositions.

Suites of this affinity are generally considered to form in anorogenic environments, as a consequence of rifting and high heat flow, or in post-orogenic environments, where similar conditions may prevail. In most cases, addition of heat, and probably also magma, from subjacent mantle, is considered to be an important causative factor (e.g., Emslie, 1978; Anderson, 1983).

Low Al_2O_3 contents and high (K_2O + Na_2O) are the most obvious major-element features of the peralkaline granites. Trace-element signatures are highly variable, but most are characterized by high Zr, F, Nb, Y and Zn. Rb contents (and those of other 'lithophile' elements such as Li, Th and U) are particularly variable. As in the case of peraluminous granites (Table 13), it is very difficult to define specialization on absolute grounds.

Although none of the granite suites in the study area is entirely of peralkaline composition, the Kennedy Mountain, Strawberry and Lanceground Intrusive suites all trend toward peralkaline compositions, and have high agpaitic indices (K+N/A > 0.9, commonly > 0.95). In terms of trace-element signatures, the Lanceground Intrusive Suite, and (to a lesser extent), the Cape Strawberry granite, resemble some of the peralkaline suites (e.g., Topsails, St. Lawrence, Flowers River and Saudi Arabia), and also compare well to the average of 'A-type' granites from Australia. Labradorian granites have significantly lower Zr, F, Y, Nb and REE contents than any of the alkaline–peralkaline suites.

An affinity between many Makkovikian granites and so-called 'within-plate' or 'anorogenic' or 'A-type' granites has been noted on the basis of comparative major and trace element geochemistry above. Although the extreme enrichments characteristic of some of the suites listed in Table 14 are not observed, this general resemblance suggests that Makkovikian granites should be considered to have potential for deposit types characteristically associated with such rocks.

Metaluminous (Subalkaline) Specialized Granites

Table 15 lists average analyses of specialized granitoid suites of generally metaluminous composition. These are associated with a variety of mineral deposits, including Sn–W in greisens, and vein-hosted and disseminated Mo–Bi–W. They include mineralized rapakivi granites from Finland (Haapala, 1988; some of these are of A-type affinity), so-called 'calcic' specialized granites from Saudi Arabia (Ramsay, 1986), and the Ackley Granite suite of southeast Newfoundland (Tuach *et al.*, 1986). The average compositions of both 'I-type' granites and 'fractionated I-type' granites, as listed by Whalen *et al.*, (1987), based on Australian data, are also shown for comparative purposes. Suites of this affinity constitute the most abundant class of granitoid rocks, and form both in continental margin environments related to subduction (e.g., the Cordilleran belt), and in post-orogenic environments (e.g., the Newfoundland Appalachians).

With the exception of the topaz-bearing Eurajoki stock in Finland, which is clearly unusual, these granites have less extreme trace-element compositions than the other specialized granites listed in Tables 13 and 14; however, their trace-element patterns are highly variable in absolute terms. Makkovikian granites are generally higher in Zr, Nb, Y and F than these suites, but have similar ranges of Rb, Th and U. Labradorian granites, on the other hand, compare well to some of these suites.

Specialized Granite–Precursor Granite Comparisons

Tables 13, 14 and 15 also list several examples where specialized suites can be directly compared to their 'precursor' or associated barren granitoid rocks. The analyses for Saudi Arabian 'specialized' and 'precursor' granites provide one such example; data for specialized granites in the Ackley Granite suite are also compared to the overall mean composition of the suite. In the Saudi Arabian examples, trace-element contrasts between specialized and precursor granites of all classes are significant, but enrichment and depletion factors are rarely greater than twofold. In the case of the Ackley Granite suite, the Sn-specialized granites are clearly more anomalous relative to the average composition, but Mo-specialized granite has enrichment-depletion factors that are below 2, and many elements change only slightly.

Enrichment or depletion factors for key trace elements relative to regional averages for the granites of the study area are of generally similar magnitude, and rarely exceed 2. Thus, in terms of their local background, several of the units listed in Table 12 may be categorized as 'specialized'. It should be noted in this context that the 'regional average' compositions utilized here include the potentially specialized rocks, and contrasts between these and barren granites are thus subdued.

DISCUSSION AND CONCLUSIONS

The objectives of this study are to improve the information base and understanding of intrusive suites in the eastern Central Mineral Belt, and assess their potential for granite-related mineralization. Both of these aims have been acheived; however, as is inevitably the case with large-scale projects of this nature, many questions remain unresolved. In this final section, some of the main findings are summarized and discussed, and recommendations are made for future investigations.

AGE, SUBDIVISION AND ORIGINS OF PLUTONIC AND VOLCANIC ASSOCIATIONS

Geochronological Data and their Implications

Major Results

Prior to, and during initial stages of this project, the voluminous intrusive rocks of the eastern Central Mineral Belt were initially grouped into two categories, i.e., syn- and posttectonic, with the latter forming the dominant association (Gandhi, 1978; Gower, 1981; Gower *et al.*, 1982; Kerr, 1986). Following the definition of the Labrador Orogen and the ca. 1650 Ma old 'Trans-Labrador batholith' in central Labrador (e.g., Wardle *et al.*, 1986; Thomas *et al.*, 1986), it was assumed that the posttectonic intrusive rocks of the eastern Central Mineral Belt were entirely of similar age (e.g., Gower and Ryan, 1986; 1987). The foliated intrusive rocks were viewed as products of the ca. 1800 Ma Makkovikian Orogeny (Gower and Ryan, 1986). Early summaries from this project made the same assumption (Kerr, 1986; 1987). U–Pb (Kerr and Krogh, 1990; Kerr *et al.*, 1992) and Rb–Sr geochronology (Kerr, 1989a) compel a reassessment of this twofold division, especially when combined with U–Pb data collected by Loveridge *et al.* (1987), Gandhi *et al.*, 1988) and Schärer *et al.* (1988). Most importantly, it is now clear that there are at least four discrete groupings of intrusive rocks.

Foliated granitoid rocks are confirmed to be older than 1800 Ma (Loveridge *et al.*, 1987; Gandhi *et al.*, 1988), as previously inferred from K–Ar and Rb–Sr data. However, the results of Gandhi *et al.* (1988) from west of the study area (see also Kerr *et al.*, 1992) imply that some may be considerably older than previously thought, i.e., older than 1900 Ma.

Massive, unfoliated intrusions, however, categorically belong to at least three groups. The oldest group (represented by the Numok Intrusive Suite, Big River Granite, Stag Bay granodiorite and Freshsteak granitoid) yields ages of ca. 1800 Ma; these are very close to those of the foliated suites, and imply a close temporal relationship. U–Pb geochronology has confirmed the presence of ca. 1650 Ma old intrusions that are temporally equivalent to the 'Trans-Labrador batholith' of central Labrador. The complex mafic to felsic intrusions of the Adlavik and Mount Benedict Intrusive suites, and three granitic associations (Monkey Hill Intrusive Suite, Witchdoctor granite and Otter Lake–Walker Lake granite) have given ages of between 1650 and 1640 Ma, thus confirming the presence of Labradorian magmatism; these form the second group. A third, previously unrecognized group of intrusions, represented by the ca. 1720 Ma old Strawberry Intrusive Suite, has now also been documented in the area. The relative abundances of these age categories are opposite to those inferred previously; Labradorian rocks are much less abundant than previously supposed, and the bulk of the granitoid intrusive rocks are of 1800 or 1720 Ma age. The sequence of ages also implies a reversal of field relations implied by Gower and Ryan (1986) and Kerr (1986; 1987), who believed that the mafic rocks of the Adlavik Intrusive Suite predated most massive granitoid rocks.

The closely similar U–Pb and Rb–Sr ages obtained from the Island Harbour Bay intrusive suite, Long Island Quartz Monzonite, Numok Intrusive Suite, Big River Granite and Freshsteak granitoid all fall in the interval 1800 ± 15 Ma (Loveridge *et al.*, 1987; Gandhi *et al.*, 1988; Kerr and Krogh, 1990). The geochronological data (and also the common geochemical traits of many of these units) strongly suggest that 'syntectonic' and 'posttectonic' Makkovikian plutonic associations are (at least in part) manifestations of the same magmatic event. They are regarded by this author as closely related, and, in comparative analyses (Kerr, 1989a) were treated as a single assemblage. These ca. 1800 Ma old Makkovikian suites may collectively represent a single pulse of magmatism that transcended a short-lived deformational event, i.e., the age difference between 'syntectonic' and 'posttectonic' suites is real, but below isotopic resolution. A second possibility is that late Makkovikian deformation at ca. 1800 Ma may have been heterogeneous in nature. As discussed by Paterson and Tobisch (1988), the response of plutons to deformation is highly variable, and the use of foliations to infer their age may be misleading.

However, it must be emphasized that the syntectonic Makkovikian association probably includes some rocks that are significantly older than 1800 Ma, as evidenced by the ca. 1837 Ma age from the Deus Cape granodiorite (Kerr *et al.*, 1992), and the 1890 Ma age reported by Gandhi *et al.* (1988) and Kerr *et al.* (1992). The weakly peraluminous, possibly anatectic, association present within the syntectonic suites is apparently absent from posttectonic suites, and may perhaps therefore be slightly older.

The ca. 1720 Ma assemblage represented by the Strawberry Intrusive Suite is also unlikely to bear a direct genetic relationship to the ca. 1800 Ma intrusions. However, in geochemical terms, there are compelling similarities between 1800 Ma and 1720 Ma granitoid rocks. It is therefore included as part of the Makkovikian assemblage in this study; it falls between post-orogenic and anorogenic magmatism, and is perhaps analogous to Late Devonian and Carboniferous

granites of the Newfoundland Appalachians (e.g., Hayes *et al.*, 1987; Williams *et al.*, 1989), which bear a similar temporal relationship to deformational events. However, recent dating of the supposedly Carboniferous St. Lawrence Granite (Kerr *et al.*, 1993) suggests that is Middle Devonian, and reduces this apparent time interval.

Further Requirements

It has not been possible to date all of the intrusive suites in the study area, and some units remain of uncertain age. The Kennedy Mountain Intrusive Suite is an important syntectonic association that may be a plutonic counterpart to parts of the Upper Aillik Group, but also has petrological and geochemical affinities to rocks known to be of ca. 1720 Ma age. Its foliation suggests that it is older than 1800 Ma, but this requires confirmation. It contains abundant zircon and sphene, and should be easy to date, perhaps also offering a chance to pinpoint late Makkovikian metamorphism via partial or complete resetting of sphene.

The potentially specialized Lanceground Intrusive Suite also requires U–Pb dating. Kerr (1989a) obtained a 1692 ± 32 Ma Rb–Sr isochron from one pluton, but felt that this had been disturbed; the very high Rb/Sr ratios of the granite render this isotopic system inherently unreliable. The distinctive geochemistry of the suite clearly sets it apart from known Labradorian granitoid rocks, but it could belong to either 1800 or 1720 Ma Makkovikian groupings. The author tends toward the former, as there are petrological similarities (e.g., hypersolvus variants, relict fayalite) between the Lanceground Intrusive Suite granites and ca. 1800 Ma old syenite of the Numok Intrusive Suite. The abundance of zircon, and high Zr content, of the Lanceground Intrusive Suite suggests that it should be very easy to date.

The two units above are probably the most important requirements in terms of clarifying plutonic associations. Other interesting avenues for geochronological studies are offerred by the Brumwater and Pitre Lake granites, which, as they appear to be of anatectic origin, should constrain the high-grade metamorphism in the Kaipokok Bay area fairly precisely. The Cape Harrison Metamorphic Suite of Gower (1981) is also of considerable interest as it is probably a remnant of an originally more extensive Early Proterozoic basement complex that underlies the eastern portion of the study area. Nd isotopic data strongly suggests an age of less than 2100 Ma (Kerr, 1989a; Kerr and Fryer, 1993, 1994).

Petrological and Geochemical Contrasts

Makkovikian Plutonic Rocks

Syntectonic Makkovikian plutonic rocks can be divided into two groups. The Long Island Quartz Monzonite, Kennedy Mountain Intrusive Suite and Melody Granite are regionally extensive, homogeneous units. There is no evidence of significant anatectic melting in their country rocks, suggesting that they were derived from well below the current level of exposure.

Minor foliated granitoid units of the Kaipokok Bay area (Brumwater and Pitre Lake granites) are confined to specific units in the basement complex or Lower Aillik Group, and, although intrusive, have contacts that are regionally concordant to layering and/or stratigraphy. Both locally appear gradational with surrounding rocks (Marten, 1977), and contain abundant metasedimentary and gneissic xenoliths respectively. There is evidence of migmatization in the country rocks, and Marten (1977) suggested that the Brumwater granite was derived from migmatitic Archean gneiss. The Nd isotopic signature of the granite (Kerr, 1989a) confirms this interpretation. The composition and setting of the Pitre Lake unit suggests derivation by anatexis of local metasedimentary rocks. Both units were apparently derived by melting of their country rocks at (or slightly below) the present level of exposure. They are the only rocks in the study area for which such a relationship can be demonstrated. The Island Harbour Bay intrusive suite was not examined directly in this study, but apparently has elements of both settings (Ryan *et al.*, 1983; I. Ermanovics, personal communication, 1988).

As discussed previously, geochemical subdivision of these rocks into a metaluminous–peralkaline association and a peraluminous association corresponds in general terms to this field subdivision. Metaluminous to peralkaline granitoid rocks are vastly dominant over peraluminous granites.

Posttectonic Makkovikian units are all of regional extent in the sense that they outcrop over hundreds of square kilometres, or occur as discrete, closely similar bodies dispersed over wide areas. Those that retain contacts with country rocks show intrusive relationships, and there is no sign of extensive migmatization around them. They are generally homogeneous, and contain xenoliths only in their marginal zones. They are thus clearly discordant magma bodies that have risen from depths well below the current level of exposure. Geochemically, there are strong affinities between these rocks and the metaluminous–peralkaline syntectonic association, even to the extent of analogous mean unit compositions. No posttectonic Makkovikian units resemble the minor peraluminous syntectonic Makkovikian rocks. Very little distinction can be made be the ca. 1800 Ma old units and the ca. 1720 Ma old Strawberry Intrusive Suite, except for the slightly more evolved character of the latter.

Thus, although it is clear that the Makkovikian plutonic assemblage includes both older and younger rocks, its generally homogeneous geochemistry supports the inference that much of it represents the product of a single pulse of magmatism at ca.1800 Ma, that transcended late Makkovikian deformation. As discussed above, geochronological data suggest the same conclusion.

Labradorian Plutonic Rocks

Labradorian plutonic rocks are much more diverse in petrology and geochemistry than their Makkovikian counterparts. They can be subdivided into compositionally expanded gabbro–monzonite–syenite suites of 'mafic'

parentage, and a variety of granitic rocks. The former are distinct from any regionally extensive Makkovikian plutonic suites, although mafic inclusions in the border zone of the ca. 1800 Ma Numok Intrusive Suite imply some type of associated mafic magmatism. Labradorian granitic (*ss*) rocks are regionally extensive units or dispersed plutons that may be connected at depth or in genesis. They show intrusive relationships with their host rocks, and there is no evidence whatsoever of anatexis in the surrounding areas. In these respects, they resemble the older plutons, and were similarly derived from well below the current level of exposure. Geochemically, they are distinct from the dominant metaluminous–peralkaline Makkovikian association, but bear some resemblance to the minor syntectonic peraluminous granites. There is, therefore, geochemical evidence that Labradorian granitoid rocks were generated either from different sources from, or by different processes to, the majority of the Makkovikian plutonic rocks.

Relationships Between Plutonic and Volcanic Assemblages

Geochemical comparisons of the Upper Aillik Group and Bruce River Group with plutonic associations suggests that they are compositionally akin to Makkovikian and Labradorian plutonic rocks respectively. The Upper Aillik Group has been variously described as alkaline (White and Martin, 1980; Payette and Martin, 1986) or calc-alkaline (Bailey, 1979; Gower *et al.*, 1982) in affinity, and it has also been proposed that its 'apparent' alkalinity may be a function of metasomatic processes superimposed on a calc-alkaline affinity (e.g., Wilton, *in press*).

Makkovikian plutonic rocks have essentially the same ambiguous geochemical features as the Upper Aillik Group; they are dominantly subalkaline and metaluminous, but evolve to locally peralkaline compositions, and are characterized by high K+N/A and F/F+M ratios. The consistency of this signature, and the similarly 'quasi-alkaline' trace-element signatures of plutonic and volcanic suites, suggests that this is a real compositional feature, and is not a function of alteration or metasomatism. Labels such as 'alkaline' and 'calc-alkaline' are purely arbitrary divisions, and Makkovikian plutonic and volcanic rocks are transitional in affinity; they are better described as 'alkali-calcic', and many of them have the major- and trace-element characteristics of so-called 'A-type' granites (cf. Whalen *et al.*, 1987).

Gower and Ryan (1987) proposed that the Upper Aillik Group was a two-stage volcanic sequence corresponding to both Makkovikian and Labradorian magmatism. Subsequent ca. 1810 Ma U–Pb ages from the so-called 'later' portion (Schärer *et al.*, 1988) invalidated this idea. However, this general concept of a two-stage or multistage sequence remains valid if the Upper Aillik Group includes equivalents of both syn- and posttectonic Makkovikian plutonic rocks. A model of this type would account for the fact that parts of the Upper Aillik Group appear only weakly deformed, whereas other parts are strongly foliated. The 1807 ± 3 Ma age reported by Schärer *et al.* (1988) from part of the Upper Aillik Group overlaps ages from both syn- and posttectonic Makkovikian plutonic rocks. However, plutonic rocks that are chronologically equivalent to the ca. 1860 Ma components of the Upper Aillik Group defined by Schärer *et al.* (1988) are not evident; the oldest syntectonic plutonic unit yet recognized is the ca. 1837 Ma Deus Cape granodiorite. There is clearly a need for precise dating of more foliated granitoid units but, more importantly, a pressing need for an improved understanding of Upper Aillik Group stratigraphy. In most respects, we are still groping in the dark with this particular problem; Kerr (1989a) observed that the Upper Aillik Group has 'the dubious distinction of being the most studied and least understood supracrustal sequence in eastern Labrador'. It is, of course, also one of the most important in economic terms, and desperately requires systematic stratigraphic and structural mapping.

Possible 1720 Ma Volcanic Suites?

A third problem concerns the possible existence of ca. 1720 Ma volcanic rocks that are equivalent to the Strawberry Intrusive Suite. There is as yet no firm geochronological evidence of such, but circumstantial Nd isotopic evidence reviewed by Kerr (1989a) points to one possible candidate. A subvolcanic feldspar porphyry from a fresh sequence of volcanic rocks east of the Stag Bay granitoid has strongly positive ϵ_{Nd}CHUR of +4 to +5, and a high-silica granitic composition. The only plutonic rocks that share this unique signature are the eastern plutons of the Strawberry Intrusive Suite. This possibility needs to be tested, preferably by dating a rhyolite from the belt. If 1720 Ma old volcanic rocks are identified, it will introduce yet another problem in understanding the Upper Aillik Group!

Speculations on Affinity and Tectonic Setting

Geochemical Affinities of Plutonic Suites

Kerr (1989a) conducted a comparative analysis of the plutonic suites using a number of representative databases. This is summarized in the section on Comparative Geochemistry. It was concluded that the characteristics of the Makkovikian assemblage are inconsistent with its development in a continental margin arc setting, as is commonly proposed for many linear or curvilinear granitoid belts. It was suggested instead that a post-orogenic, possibly post-collisional, setting is most consistent with the both the regional geological setting of the Makkovikian assemblage and its geochemical characteristics. Geochemically, it is transitional between younger post-orogenic granitoid suites such as those in Newfoundland, and the truly anorogenic, partially peralkaline granites such as those of northern Labrador. The Makkovikian assemblage has many features that resemble those of so-called 'A-type' or 'anorogenic' granites. Such features have been noted amongst Proterozoic granitoid suites in other parts of the world (e.g., Wyborn *et al.*, 1988), and have led some to suggest a radically different (ensialic) tectonic setting for such rocks.

The Labradorian assemblage is far more difficult to classify via geochemical comparisons, mostly because it is only the northern fringe of a much wider belt and may not represent its full compositional range. It includes a range of compositions similar to those of volcanic-arc batholiths, but has a bimodal compositional spectrum, and is generally more siliceous and potassic than typical arc suites. Labradorian granitic rocks have some slight tendencies toward Fe-enrichment and high K+N/A, but not to the same degree as the Makkovikian assemblage. They do not show the distinctive trace-element signatures of Makkovikian granites, and could belong to either volcanic-arc or post-collisional assemblages. Labradorian mafic and intermediate rocks have affinities to high-K calc-alkaline or shoshonitic associations, and fall dominantly in the calc-alkaline basalt field.

A distal portion of a magmatic arc (i.e., an area well removed from the locus of subduction) is one possible setting for Labradorian magmatism. This is consistent with its siliceous and potassic character relative to proximal volcanic-arc batholiths. The lack of a recognizable Labradorian 'orogeny' in the study area could be then attributed to its great distance from the main portion of the orogenic belt. However, similar assemblages also occur in post-orogenic, post-collisional settings, where granite compositions overlap partly with those of mature or distal arcs. At the present time, it is very difficult to select between these alternatives.

A Gondwanaland Analogy to the Makkovik Province?

Kerr (1989a) attempted to place these magmatic events into a tentative plate tectonic model. He suggested that Makkovikian magmatism mostly recorded thermal events that followed the accretion of a belt of 'juvenile' Proterozoic crust against the margin of the North Atlantic Craton. Remnants of the latter may be preserved in the grey gneisses of the Cape Harrison area, which, on the basis of Nd model ages, are unlikely to be older than ca. 2100 Ma (Kerr, 1989a; Kerr and Krogh, 1990). Nd data from Makkovikian intrusions demonstrates that their sources were dominantly Proterozoic in the east, but included significant amounts of Archean material in the west (Kerr, 1989a; Kerr and Fryer, 1993, 1994). Kerr (1989a) further suggested that subsequent Labradorian magmatism records the establishment of a new consumptive margin (i.e., a new subduction zone) within the area now represented by the Labradorian Orogenic Belt; Labradorian magmatism in the Makkovik Province represents the distal fringe of this province, and was not therefore associated with penetrative Labradorian deformation.

Kerr (1989a) suggested that a possible analogy to the development of the Makkovik Province and adjacent areas may be provided by the late Paleozoic to recent evolution of southern South America, as described by Ramos (1988), Rapela and Kay (1988) and Kay *et al.* (1989). In this area, the Carboniferous accretion of continental margin and oceanic 'exotic' terranes onto the margin of Gondwanaland was followed by protracted high-silica magmatism of Carboniferous and Permian age. High-silica, A-type granites and rhyolites were generated during earliest Jurassic times. Contemporaneously, a new subduction zone was initiated to the 'west', eventually producing the Jurassic to Recent calc-alkaline magmatism of the Andean belt, which is partly superimposed on the older magmatic belts. Quartz-diorite plutons of ca. 1710 Ma age within the Groswater Bay Terrane of the Labradorian belt (Schärer *et al.*, 1986) possibly represent subduction-related plutonism that commenced whilst the late Makkovikian Strawberry Intrusive Suite was being emplaced in the study area.

MINERAL POTENTIAL OF SELECTED GRANITOID SUITES

Based on comparisons with regional average compositions and affinities to other specialized granites and their demonstrated or inferred relationships to known mineralization, the following units are suggested as possible candidates for specialized granites, and assessed below. The discussion is not organized in order of importance or priority, but simply according to plutonic grouping.

Syntectonic Makkovikian Granites

Kennedy Mountain Intrusive Suite

Although the mean composition for this suite is not significantly enriched compared to regional averages, examination of unit averages suggests that the Kennedy Mountain granite itself and the Cross Lake granite both show more significant compositional evolution. With respect to trace-element patterns, the effects of Na-metasomatism noted must also be considered. There is a clear correlation between alkali disturbance and depletion of incompatible elements such as Rb, suggesting that measured levels of such may be less than reliable.

The presence of these metasomatic alteration patterns is itself a powerful argument for considering these suites as candidates for mineralization. Closely similar alteration patterns are seen in the U-mineralized felsic volcanic rocks of the Upper Aillik Group, and the Kennedy Mountain Intrusive Suite may represent a plutonic equivalent to these. Na-metasomatism is commonly related to albitization of feldspars, and this type of alteration is widely associated with granite-related mineralization. However, there is only limited evidence of a spatial relationship between any of these granites and mineralization. Pegmatitic phases are common in several areas, notably in fine-grained variants of the Cross Lake granite, and Wilton (*in press*) describe syntectonic amazonite-bearing pegmatites with anomalous radioactivity west of Makkovik. The greatest role of these suites in mineralization may have been as heat and fluid sources for hydrothermal uranium mineralization in the Upper Aillik Group, as suggested by Gower *et al.* (1982), but they merit further examination.

Pitre Lake Granite

The Pitre Lake granite has a highly evolved composition, characterized by strong enrichment in Rb, Li and F. It is a

typical S-type granite of the type believed to be derived by anatexis of sedimentary protoliths, and compares well to average compositions of tin-bearing peraluminous granites elsewhere in the world (Tables 13, 14 and 15). The most important negative factor is the small size of the intrusion, which probably limits the ability of magmatic differentiation processes to concentrate significant amounts of ore elements.

Parts of the Island Harbour Bay Intrusive Suite

Only limited geochemical data are available from these rocks, as they were not examined in detail during this project. However, as shown by variation diagrams, a few of the granites collected by B. Ryan (personal communication, 1988) are compositionally akin to the Pitre Lake granite. There are, however, no significant areas of metasedimentary gneisses north of Kaipokok Bay (Ryan *et al.*, 1983), so possible source materials for these are not yet clear. During a brief visit to the Turnavik Islands in 1986, the author discovered a thin (15 cm), muscovite-rich zone, which closely resembles a greisen, traversing (cutting?) a fine-grained, sugary-textured leucogranite. The 'greisen' contains 478 ppm Li, 706 ppm Rb, 110 ppm Ga, 98 ppm Sn and over 12 000 ppm fluorine. The leucogranite has a similar, but less intense, enrichment pattern. Both compositions compare well to tin-bearing granites listed in Tables 13, 14 and 15. Radioactive pegmatites north of Kaipokok Bay have received limited attention from BRINCO and Placer Development; Ryan *et al.* (1983) suggest that these are linked to granites of the Island Harbour Bay intrusive suite. The relationship of the Turnavik islands granites to this suite is unknown. Some further assessment of the area north of Kaipokok Bay is warranted, as it may include high-level granites of Makkovikian or Labradorian age.

Posttectonic Makkovikian Granites

Strawberry Intrusive Suite

With the exception of the Bayhead granite, all the plutons within this suite show significant major andor trace element enrichment-depletion patterns relative to regional averages. This is most marked for the Cape Strawberry granite, which also shows the greatest variability in both texture and composition in the field.

In the case of the Cape Strawberry granite, there is a clear spatial relationship to a number of disseminated to stockwork Mo occurrences, particularly on the southern and western margins, and possibly also a link between the granite and Pb–Zn mineralization in quartz-carbonate veins. In a review of possible specialized suites, Kerr (1988b) reported evidence of cryptic geochemical zonation similar to that observed in other mineralized high-silica granites (e.g., Hildreth, 1986; Tuach *et al.*, 1986). The Dog Islands granite hosts minor Cu–Pb–Sn mineralization associated with an aplitic vein, and the suite as a whole shows enrichment in Sn compared to other units (Kerr, 1988b); there may also be a link between the Tukialik granite and vein-hosted Mo in the Jay Lake area. Biotite-rich layered zones in the Cape Strawberry and Dog Islands granites are highly anomalous in Zr, Y and REE; these layers represent a type of "magmatic" mineral occurrence that has not previously been recognized in granites. The widespread alteration of primary biotite to chlorite in the Strawberry Intrusive Suite granites provides evidence for pervasive hydrothermal activity in these rocks.

All of the above features indicate that these rocks have many of the characteristics of specialized granites.

Of the individual plutons in this suite, the Cape Strawberry granite probably has the most favourable combination of circumstances. Contacts with its host rocks are preserved, and the distribution of granite bodies in the area strongly suggests that the upper contact of a larger body lies close to the surface over much of the peninsula between Ford's Bight and Big Bight; the abundance of minor intrusions, such as pegmatites and dykes, attests to the proximity of a posttectonic magma chamber to areas underlain by the Upper Aillik Group. This entire area is worthy of further investigation, and is known to contain a great number and variety of mineral occurrences. The Tukialik granite is also of interest, as it contains an enclave of metavolcanic rocks that may be a remnant of its roof zone, and is commonly fluorite-bearing. No volcanic rocks are preserved in the Dog Islands granite; however, Kerr (1989a) and Kerr and Krogh (1990) speculated that fresh volcanic rocks exposed in the nearby Benedict Mountains may be extrusive equivalents of eastern plutons of the Strawberry Intrusive Suite.

East of a north–south line passing through Adlavik Bay, exploration activity has been extremely limited, and the Tukialik and Dog Islands granites have never been prospected.

Lanceground Intrusive Suite

The Lanceground Intrusive Suite is presently of unknown potential. These rocks are somewhat similar in composition to the Strawberry Intrusive Suite, but have greater Zr, Y and REE enrichment, and a more intense depletion of Sr and Ba. They have evolved trace-element signatures in comparison to regional average compositions (Table 12). All plutons from the Lanceground Intrusive Suite include rocks of hypersolvus affinity, suggesting high levels of emplacement.

Granites of the Lanceground Intrusive Suite have the closest geochemical affinity to peralkaline, anorogenic suites associated with Zr–Y–REE mineralization, but have less extreme trace-element patterns. Potential for such mineralization is confirmed by the presence of 4500 ppm Zr (0.45 percent Zr) in a minor intrusion associated with the suite. A number of scattered U occurrences in the Winter Lake–Bernard Lake area, including the Ag-bearing 7-11 showing are adjacent to the northwest contact of the Pistol Lake granite, but there is no definitive evidence of a connection.

Labradorian Plutonic Rocks

Syenite and Granite of the Mount Benedict Intrusive Suite

This unit has the most highly evolved trace-element composition within the study area, excluding the Pitre Lake granite. As discussed, such features probably reflect the protracted fractional crystallization of a mafic parental magma. The generally fine grain size, locally subvolcanic appearance, and restriction to topographic highlands strongly suggests that this unit is a high-level roof phase. However, no roof pendants have been identified in the area, suggesting that the actual upper contact surface has been removed by erosion. This is unfortunate, as this probably represents the most favourable area for mineralization. There is no established relationship between this unit and mineralization; however, Gower (1981) notes disseminated molybdenite, fluorite and pyrite at three locations, based on observations by Douglas (1953) and Stevenson (1970). These rocks are located in an area that has received very little exploration.

Monkey Hill Intrusive Suite

The Monkey Hill Intrusive Suite presents something of an enigma. There is no doubt about the association between stocks assigned to this suite and mineralization in the Round Pond area, south of Makkovik (MacDougall, 1988), where there is a clear spatial association, and evidence of strong alteration in high-level intrusions. Similarly, there is clear endocontact Mo mineralization in the Duck Island granite. The great number and variety of mineral occurrences in the Round Pond area suggests that it has a high potential for further discoveries.

In terms of accepted criteria for recognition of specialized granites, the Monkey Hill Intrusive Suite is anomalous. It fits physical–mineralogical criteria such as a high level of emplacement and evidence for alteration (e.g., widespread chloritization of biotite), but has a relatively unevolved trace-element pattern, which is not significantly different from regional average compositions. In this case, the unequivocal relationship to mineralization must override geochemical criteria based on comparative studies, and all plutons of the suite must be viewed with interest. The main body of the Monkey Hill Intrusive Suite is in a well-prospected area, and shows little relationship to mineralization; it may therefore be of lesser interest than the other satellite bodies. Those in the east have received very little attention in terms of prospecting. However, the most favourable combination of circumstances is undoubtedly present in the Round Pond area.

Witchdoctor and Burnt Lake Granites

MacKenzie (1991) has linked the fine-grained granites at Burnt Lake to minor base-metal mineralization in the Aillik Group; the granite itself hosts a small but high-grade Mo showing. As in the case of the Monkey Hill Intrusive Suite, these direct indications of potential are at variance with trace-element patterns that are not significantly evolved compared to regional averages. The potential of these granites is difficult to assess, as their relationship to exocontact mineralization is nowhere near as well established as at Round Pond.

RECOMMENDATIONS

Geological and Geochemical Studies

Geological, geochemical and geochronological work conducted by this project has clarified our understanding of intrusive rocks in the eastern Central Mineral Belt, but several avenues still remain unresolved.

Geochronologically, key issues include the dating of foliated granitoid units that may help to constrain timing of Makkovikian deformation and metamorphism more precisely, and investigation of undated plutonic and volcanic suites that may belong to the 1720 Ma magmatic episode represented by the Strawberry Intrusive Suite.

Geologically, our knowledge of the large and complex intrusion north of Kaipokok Bay (Island Harbour Bay intrusive suite) is presently incomplete. A recent paper by Ermanovics (1992) addresses some of these problems, but does not include significant amounts of geochemical data. A number of individual plutonic suites identified by this study would form interesting research topics for geochemical and isotopic studies aimed at their petrogenesis and evolution.

If, as alluded to here, the Upper Aillik Group contains equivalents of both syn- and posttectonic Makkovikian plutonic suites, there is a great need for improving our knowledge of this very important supracrustal package. Our regional understanding of the Upper Aillik Group is incomplete, because most studies have been localized efforts by exploration companies or government geologists. The multistage nature of plutonism in the eastern Central Mineral Belt implies that similar complexity may exist within this volcanic sequence.

Mineral Exploration

In terms of mineral deposits associated with granitoid rocks, two areas stand out. The first is the Round Pond Area, where widespread and varied small-scale mineralization suggests potential for more significant discoveries. The second is the peninsula between Ford's Bight and Big Bight, where evolved granites of the Strawberry Intrusive Suite are inferred to lie at shallow depths, and exocontact mineralization is also known to occur. These are obviously the most favourable areas, as magmatic–metallogenic links can be demonstrated in both. In terms of previous evaluation, very little work has been conducted in either since the mid-1960s; of the two, the Round Pond area has received by far the most attention.

Comparative arguments suggest that other portions of the Strawberry and Monkey Hill Intrusive suites may also have potential. The former display evidence of geochemical

specialization, but geochemical arguments are more difficult to apply to the Monkey Hill Intrusive Suite. Granites of the Strawberry Intrusive Suite, in the east of the area, have received virtually no attention to date.

In addition to these suites, this study has identified a number of possibly specialized units, such as the Lanceground Intrusive Suite and syenites of the Mount Benedict Intrusive Suite, that are not presently known to be associated with mineralization. These have received very little detailed exploration attention, and their potential is largely unknown. It is difficult to fully assess these units within the limitations of this regional study, but their evolved geochemistry suggests that they merit consideration in future exploration work. There are also indications of highly evolved granites at Pitre Lake, and possibly also within the area mapped as Island Harbour Bay intrusive suite, to the north of the study area.

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MAPS NOT FILMED

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